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CONTENTS:

ANATOMY OF *Platanus occidentalis*, ... *Maude Marie Baird.*

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Anatomy of *Platanus occidentalis*.

MAUDE MARIE BAIRD.

Plates LXV-LXXVI.

THE natural habitat of *Platanus occidentalis* is the flood plain of streams. The tree from which the material for this work was obtained is growing upon the campus of the University of Kansas, on prairie land which, though sheltered from the south winds, is at a considerable elevation above the Kansas river a half mile away, so that its water supply is less than it would receive in its natural habitat. This condition may have affected its anatomical structure to some extent. Miss Anna M. Starr ('97) has shown that there is a marked difference between members of a species of plant growing in mesophytic situations and members of the same species growing in xerophytic situations. She gives the following interesting comparison of *Platanus occidentalis* growing in a swamp habitat and the same plant which, by increased length of stem, has been able to keep pace with a moving dune which is passing over the place where it is growing.

In the following table S stands for the swamp form and X stands for the dune form:

LEAF.	S.		X.	
Thickness	152 μ		199 μ	
Thickness of upper epidermis	23	= 15%	25	= 12%
Depth of palisade	52	= 34%	63	= 32%
Depth of sponge	62	= 41%	92	= 46%
Tickness of lower epidermis	16	= 10%	19	= 10%
Outer wall of epidermis	4		2.8	

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STEM.

	S.	X.
Number of vessels in the octant	66	69
Average diameter of the larger vessels	35 μ	46 μ
Thickness of walls of vessels	3.2	3.2
Thickness of walls of fibers	5	5
Lumen of the fibers	6.4	7
Number of growth rings	3	2
Sclerenchyma	100	116
Collenchyma	56	108

These tables show that, in comparison with the swamp form, the xerophytic form has thicker leaves, larger and more numerous water tubes in the stem, and more strengthening tissue in the bark.

ANATOMY.

The Leaf.

The leaves when young are very densely covered with two kinds of hairs. One sort (fig. 1) has a central axis about .24 mm. long, consisting of a straight row of elongated cells. This axis bears branches in whorls of three or four, each branch being composed of one or two cells, the longest of these cells being about .17 mm. in length. The other kind of hairs (fig. 2, *a*) are glandular, and consist of a short stalk of one cell surmounted by a globular cell about .026 mm. in diameter. The average length of the glandular hairs is .04 mm.

The lower epidermis is two-thirds as thick as the upper. The outer part of the wall of the upper epidermis is cutinized, as shown by its red color when stained with Sudan III. The inner part of the wall is cellulose. The entire outer wall of the lower epidermis is cellulose, but is covered by cuticle. The guard cells of the stomata are raised a little above the surrounding cells (fig. 5), and each guard cell has beneath it two or three relatively small epidermal cells as shown in cross section in fig. 5, *b*, and in surface view in fig. 6, *b*. These cells differ from the surrounding epidermal cells not only in size but also in cell contents, as will be shown in the chemical section of this paper. In all the leaves examined no stomata were found on the upper epidermis; but in Solereder (p. 780) the statement is made that stomata have been found upon the upper epidermis of this species. Upon the lower epidermis the stomata average 124 to the square millimeter. The average length of the openings of the stomata is .002089 mm. Using

Brown and Escombe's formula for finding the area of the stomatal openings per unit area of surface, $A = l \times w \times \frac{\pi}{4} \times$ number of stomata, we have .006567 × .00289 × .7854 × 124 (number of stomata per sq. mm.) = .01336 sq. mm. = area of the stomatal openings per sq. mm.; that is, when the stomata stand open, the stomatal openings form about 1⅓ per cent of the area of the lower leaf surface.

In the leaves which I studied there was only one layer of palisade cells, the usual layer just beneath the upper epidermis, and not an upper and lower layer as Solereder states (p. 780).

Fig. 7 is a surface view of a leaf embracing the epidermal, the palisade, and the vascular bundle systems. It shows well the free endings of the tracheids in the ground tissue of the leaf. The greatest distance between the ultimate endings of veins, or between an ultimate ending and the nearest vein, is not more than .08 mm. Some of the tracheids of the leaf have annular or scalariform thickenings (fig. 8, *t*), and others have transversely placed small oval bordered pits as in the tracheids of the wood. The border parenchyma of the veins of the leaf is composed of elongated cells with rather thick walls containing numerous pits (fig. 8, *k*). The midrib and the larger veins in the mature leaves have heavy strands of bast fibers, or these united into a ring, surrounding the group of vascular bundles (fig. 19, *b*.) Near the leaf blade the vascular bundles of the petiole are arranged in either two or three rings, one above the other, as shown in figure 20. Farther down the petiole the bundles are arranged as shown in figure 21. Just above the place where the petiole opens to include the bud the vascular bundles become divided into groups which form a single ring (fig. 23). The individual strands separate rather widely in the part of the petiole which incloses the bud (fig. 24), and enter the stem in this condition. Figures 25 to 28 show how these groups of bundles approach the ring of vascular bundles of the stem and occupy the leaf-trace gaps.

Figure 2 represents a cross section of a very young leaf. No cell walls have thickened excepting the walls of three or four tracheids. Figure 3 shows a cross section of the midrib of a somewhat older leaf. More differentiation of tissues is shown. The cells have increased, not only in number, but also in size. The walls of the cells which are to become bast fibers and the

outer wall of the epidermal cells have not yet begun to thicken. Figure 4 shows part of a cross section of a mature leaf. The epidermis has become cutinized and the walls of the bast fibers have become thick and lignified.

The Peduncle.

The peduncle has remarkably thick, strong bundles of bast fibers just outside the phloëm (fig. 35, *g*, and fig. 36, *k*). These strands of bast persist long after the rest of the peduncle has disintegrated. The fruit hanging suspended by these flexible threads is tossed about by the wind. This seems to be a device for scattering the seeds when the balls of fruits begin to fall to pieces in the spring.

The Buds.

The buds (fig. 30) while forming are entirely inclosed in the bases of the petioles. In winter condition they are protected by cone-shaped scales (fig. 34). The outer scale is thick and hard. The next (fig. 34, *b*) is covered by a mass of resin through which project numerous hairs about 2 millimeters long. The inner epidermis of this scale contains in some places as many as 1200 crystals of calcium oxalate to the square millimeter. On removing this scale one leaf is exposed, but the remainder of the leaves and the inflorescence are inclosed in still another conical scale densely covered with straight hairs 2 millimeters long, consisting of a chain of about four elongated cells. If the bud contains an inflorescence, the inflorescence is terminal as shown in figure 31, and there is a series of foliage leaves below it. Such a limb continues its growth by a lateral bud in the axil of the last leaf. The peduncle which terminates the main axis is pushed to one side by the development of the axillary bud at its base, which then has the appearance and later performs the function of a terminal bud. Usually a large, vigorous bud and one or two smaller buds are inclosed together in the same outer scales. The weaker buds usually do not develop. Some of them begin to unfold, and then fall. The terminal bud may contain one or two flower buds, one or two leaf buds, or both leaf and flower buds. The terminal bud may produce either pistillate or staminate flowers, and the same thing is true of the lateral buds.

Figures 37 to 42 show how the rings of vascular bundles of three separate buds merge into the one ring of the stem

which bears them. Just below the terminal bud there is an enlargement of the stem. In this part of the stem there is an extra amount of pith, containing a rich store of food for the unfolding leaves of the following season. This pith is lignified and plain pitted. A mass of stone cells is found at one side of the stem in this region, just beneath the peduncle or just beneath the fundament of a flower bud which never develops.

The Bark.

There are bast fibers in the young bark, occurring usually in large bundles just outside the phloëm (fig. 44, *b*), but scattered fibers also occur in the same zone. These bast fibers vary from .3 millimeter to 1 millimeter in length. No secondary bast is formed. After a time phellogen is formed within the secondary phloëm, and the outer bark including all the bast fibers is shed, so that the bark on the older limbs contains no bast fibers. The walls of the cells of the medullary rays in the bark become much thickened and pitted. In the rays groups of lignified cells alternate with groups of unlignified cells. The part of the ray formed early in the season becomes lignified, while the part formed late remains cellulose. In both young and old bark masses of lignified parenchyma cells are scattered through a ground mass of cellulose parenchyma cells. The older bark contains a very large proportion of stone cells (fig. 46, *s*).

The Wood.

The wood (fig. 52) is composed of tracheal tubes, wood parenchyma, fiber tracheids, and the parenchyma of the medullary rays. There are no wood fibers. The greater part of the wood is composed of fiber tracheids. The tracheids, the shape of which is shown in figure 55, have an average length of .64 mm. and an average width of .0178 mm. These fibers have oval bordered pits placed obliquely (fig. 52, *k*). The wood parenchyma, of which there is little, has plain pits and lies next to the tracheal tubes. The largest tracheal tubes have a diameter as great as .075 mm. These tubes have oval bordered pits arranged in transverse rows (fig. 52, *w*). In a longitudinal section of one of the largest of these tubes there are as many as seven of these pits to the row. By performing the following experiment the length of the tracheal tubes was found to be 22 cm.:

The bark was removed from a straight shoot and the wood was covered with wax. One end was fitted with a glass funnel, and the other end was passed through a rubber cork into a side delivery flask almost full of water, the end of the shoot extending below the surface of the water. The air was then exhausted from the flask by means of a filter pump, and the shoot was shortened until bubbles of air streamed from the lower end. Mercury was then poured into the funnel and the shoot was shortened a little at a time until a spray of tiny drops of mercury began to fall from the lower end of the shoot, showing that some of the tracheal tubes extended the entire length of the shoot. The shoot used was four years old at one end and five years old at the other.

In tangential section there are about three medullary rays to the square millimeter. These rays vary in width from one to twelve cells, or from .034 to .216 mm., and in vertical length from nine to one hundred forty cells, or from .15 mm. to 2.42 mm. The cells of the rays are plain pitted and have an average width vertically and tangentially of .03 mm., and vary in length from .013 mm. to .1 mm.

A longitudinal section was made through the region of the stem where the old wood joined the new wood (fig. 58). The xylem of the old wood was so perfectly connected with that of the new wood that no distinct line of division could be made out. However, there were shorter tracheids at the close of a year's growth, and there was a difference between the old and the new pith, the new pith being made up of larger cells and containing less stored food (fig. 59).

CHEMICAL TESTS ON CELL CONTENTS.

The Leaf.

Leaves that had been in bright sunlight for several hours brought in and tested at once for starch with iodine showed the presence of much starch.

Sections of the same leaves boiled with Fehling's solution showed great numbers of crystals of cuprous oxide, especially in the palisade cells.

Sections of leaves in alcannin over night showed no oil. Sections of leaves in Sudan III over night showed no oil, except here and there in the epidermis.

Sections of leaves were treated with methylene blue as a

mucilage test. The palisade cells, certain cells in both the upper and lower epidermis, and from four to six cells beneath each stoma took the stain (figs. 5 and 6).

Sections of leaves which had been preserved in formaldehyde, when boiled in Fehling's solution, showed no cuprous oxide crystals, probably because the sugar had been soaked out of them. The same sections left in Fehling's solution over night showed a great number of crystals of cuprous oxide in masses. Left another night, the masses grew larger. This reaction indicates the probability of glucosides.

A section of the leaf boiled in Millon's reagent showed red color in the palisade cells and in some of the epidermal cells, indicating the presence of proteid. A section of leaf treated with concentrated nitric acid and dilute ammonia showed orange color for the contents of the palisade cells, some of the epidermal cells and some of the spongy parenchyma. This color reaction indicates proteid. Sections treated with ferric chloride turned very dark in color, especially the palisade cells, indicating that there is much tannin in the leaf.

The sticky substance between the two outer bud scales is not soluble in warm water; therefore it is not mucilage. It is soluble in alcohol and xylene, which shows that it is resin.

The Bark.

Sections treated with iodine showed the presence of much starch and proteid in the parenchyma of the bark.

Fehling's solution showed the bark to be loaded with sugar.

Alcannin and Sudan III showed granular particles having the appearance of oil.

Traces of volatile oil were obtained by distillation. Cold cover glasses were passed back and forth past the mouth of a tube in which small pieces of bark were being heated. The volatile oils passed over with the steam and were condensed on the cover glasses.

Methylene blue showed the presence of no mucilage.

Some sections were soaked two days in water. Part of these, boiled at once in Fehling's solution did not show crystals of cuprous oxide. The rest of the sections put into Fehling's solution and left in a warm oven over night were full of crystals in the region of the bark, indicating that there is probably much glucoside here.

Pieces of the bark were boiled in water. Some of the water boiled with Fehling's solution showed minute crystals of cuprous oxide. These were removed by filtering, more Fehling's solution was added, and the solution was left in an electric oven over night. No more crystals formed, showing that no glucoside soluble in hot water had been formed. A section boiled in Millon's reagent showed the cell contents red in some of the cells of the medullary rays, some in the phloëm, and many in the parenchyma of the bark. The cambium was a continuous line of red. Millon's reagent caused a heavy white precipitate in the parenchyma of the bark. Sections of the bark soaked in dilute potassium hydroxide, chloroform, alcohol, hot water, and salt water still gave the precipitate on being treated with Millon's reagent. A section soaked in dilute HCl and then treated with Millon's reagent gave no precipitate showing that salts either of calcium oxalate or calcium carbonate are present in the bark. A section was treated with HCl, and since no bubbles of gas were given off the precipitate must be due to calcium oxalate and not to calcium carbonate.

A section treated with nitric acid and then with ammonia showed the presence of much proteid in the bark beginning with the cambium. Ferric chloride, copper acetate, and chromic acid all showed the presence of tannin in some cells of the phloëm and in most of the parenchyma of the bark. Bits of bark were put into dishes containing alcohol, alcohol ether, and xylene. The next day bits of Swedish filter paper were put into the dishes and the fluid allowed to evaporate. Then part of the pieces of filter paper from each dish were put into alcannin and part into Sudan III, testing for oil, and part into copper acetate as a test for resin, with the following results:

I. Alcohol extract.
   a. In alcannin. Small red bodies in great numbers clinging to the fibers of the paper. Also many larger bodies composed of aggregations of the smaller ones.
   b. In Sudan III. Same sort of bodies stained bright red.
   c. In copper acetate. Same bodies stained a deep brown. Fibers of the filter paper also covered with a brownish-green film.

II. Alcohol-ether extract.
   a. In alcannin. Very numerous large bodies with irregular outline stained red.
   b. In Sudan III. Same bodies bright red.
   c. In copper acetate. Same bodies brown.

III. Xylene extract.
   a. Alcannin. Red patches in great numbers without definite outline.
   b. Sudan III. Same spots or patches stained a yellowish-red.
   c. Copper acetate. Fibers of the paper were covered with a grayish-green film. Denser patches between the fibers were of the same color.

Since the material extracted had every appearance of being oil when treated with alcannin and Sudan III, and since it did not become emerald green when treated with copper acetate, as resin would do, the conclusion would be that it was oil, but on being treated with Tunmann's saponifying reagent there was no saponification.

Wood.

The medullary rays and pith of young wood and the rays of older wood are loaded with starch of different kinds, as shown by the different shades of blue when stained with iodine. There is also starch in the wood parenchyma.

Fehling's solution showed that sugar is associated with starch in the pith, wood parenchyma and medullary rays.

Alcannin and Sudan III showed no oil in the wood.

Bits of wood were put into alcohol, alcohol-ether, and xylene, and the same tests were made as the last recorded above for the bark. Nothing was extracted by these solvents, showing that the wood does not contain oil or resin.

Methylene blue did not show mucilage. Glucoside tests showed the presence of no glucosides in the wood.

Millon's reagent did not give the reaction for proteid in a section of wood five years old. In young wood it showed occasional cells in the pith and medullary rays containing proteid.

A section of wood treated with nitric acid and ammonia on a slide showed occasional cells in pith and rays which contain proteid, such cells being stained a deep yellow.

Ferric chloride showed tannin in the wood parenchyma, and in some of the cells of the medullary rays and pith.

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PLATE I.

FIG. 1.—Upper end of pneumatocyst, showing "bald-head" with the bases of the frond clusters.

FIG. 2.—View of kelp bed with bald-heads in foreground.

FIG. 3.—Upper end of pneumatocyst covered by *Lacuna* eggs.

FIG. 4.—Upper end of pneumatocyst, showing tracings made by *Lacuna* when eating.

FIG. 5.—Fragments of frond with several snails; badly eaten.

FIG. 6.—Float, showing appearance at close of experiment.

FIG. 7.—Colonies of *Membraniphora membranacea* on a frond.

PLATE I.

PLATE II.

FIG. 1. Bleached leaf, showing venation. × 20. *a*, Water-storage tissue between the three largest veins.

FIG. 2. Diagram of a cross section of leaf, showing arrangement of tissue. × 70. *b*, Photosynthetic tissue; *c*, conducting tissue; *e*, water-storage tissue; *d*, midrib.

FIG. 3. Cross section of leaf. × 130. *f*, Epidermis; *g*, stoma; *h*, photosynthetic cells; *i*, vascular bundle; *j*, cells near the veins which contain chloroplasts; *k*, resin gland; *l*, resin duct; *m*, water-storage cells; *n*, tracheids.

PLATE II.

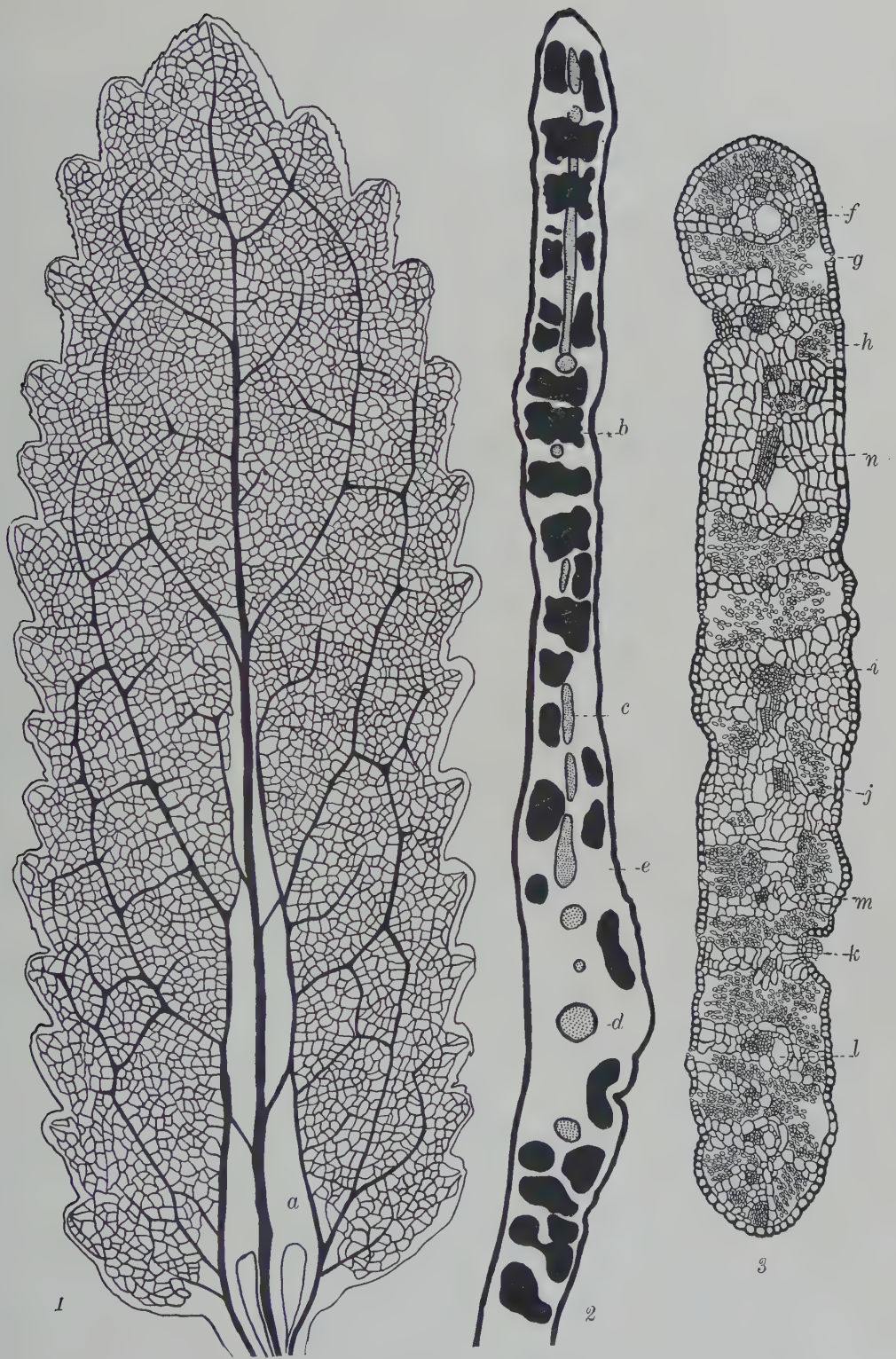


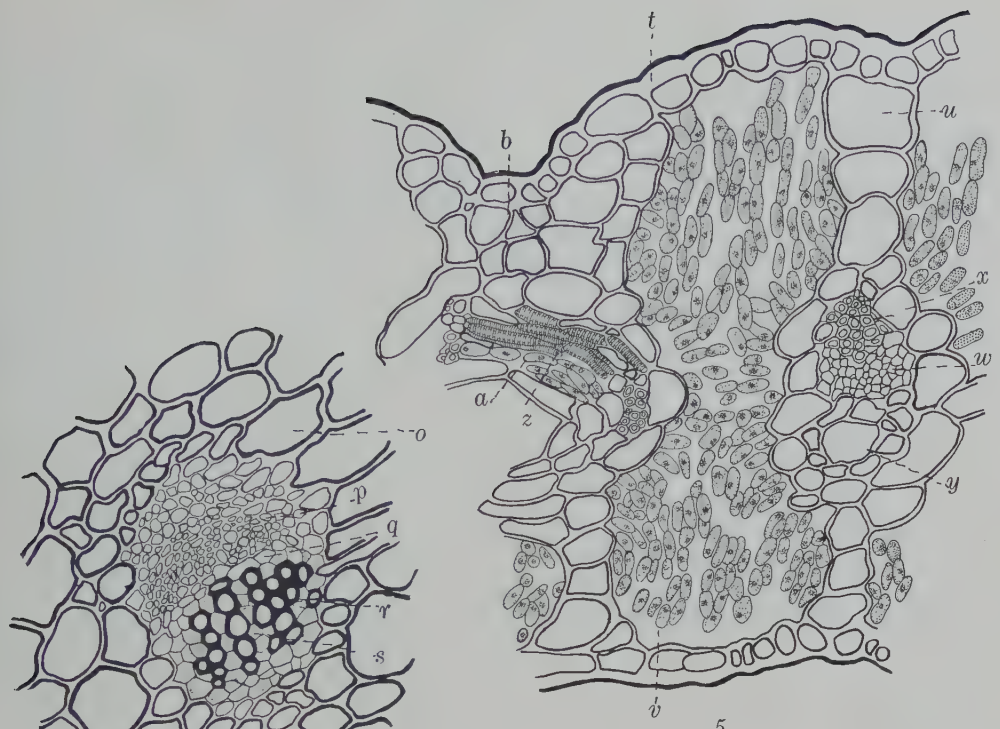
PLATE III.

FIG. 4. Midrib of leaf. × 500. *o*, Water-storage cells; *p*, phloem of midrib; *q*, conjunctive parenchyma separating xylem and phloem; *r*, tracheids; *s*, xylem parenchyma.

FIG. 5. Cross section of portion of leaf. × 500. *t*, Epidermis; *u*, water-storage cells; *v*, photosynthetic cells; *w*, phloem of a vascular bundle; *x*, xylem of a vascular bundle; *y*, resin duct, *z*, tracheids; *a*, photosynthetic cells; *b*, water-storage cells.

FIG. 6. Tangential section of leaf. × 300. *c*, Water-storage cells; *d*, photosynthetic tissue.

PLATE III.



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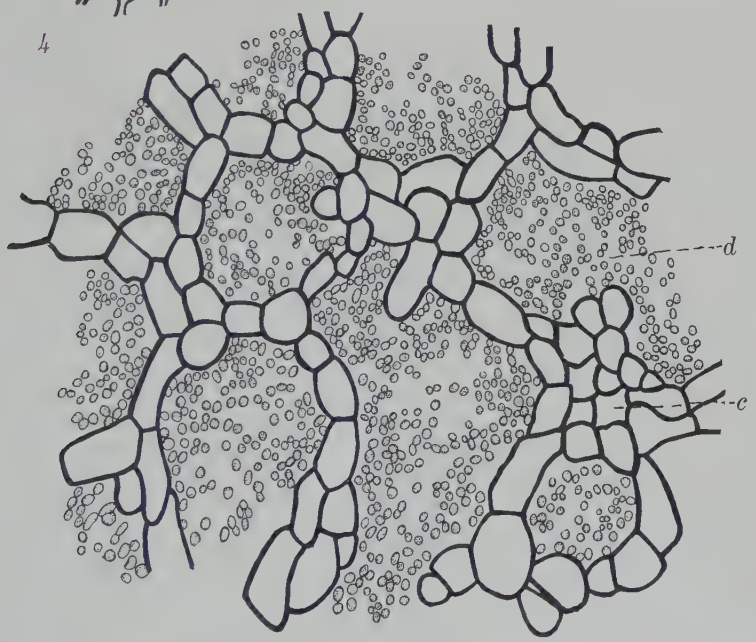

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PLATE IV.

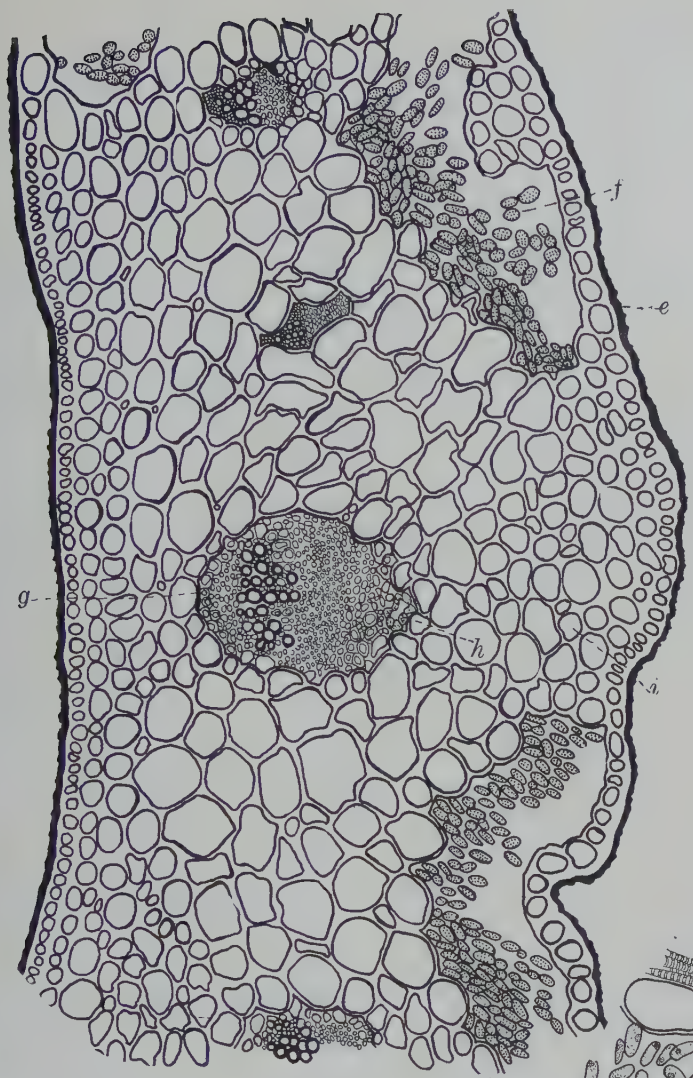
FIG. 7. Cross section of leaf through the midrib. × 300. *e*, Epidermis, showing cuticle; *f*, photosynthetic cells; *g*, midrib; *h*, resin duct; *i*, water-storage cells.

FIG. 8. Longitudinal section of resin duct. × 500. *j*, Starch sheath; *k*, cells of resin duct; *l*, collenchyma.

FIG. 9. Cross section of resin duct. × 500. *m*, Resin duct; *n*, bast; *o*, starch sheath; *p*, collenchyma.

FIG. 10. Tangential section of leaf. × 500. *q*, Photosynthetic tissue; *r*, veins; *s*, water-storage cells.

PLATE IV.



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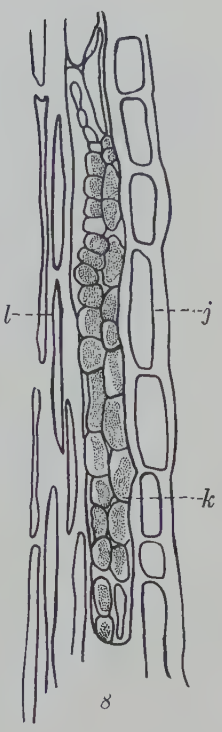

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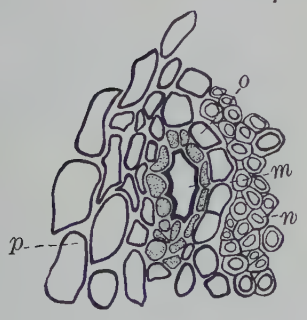

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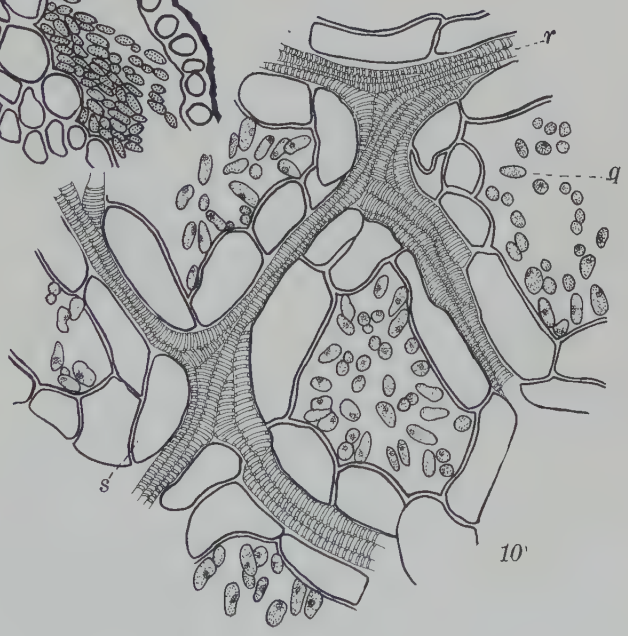

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PLATE V.

FIG. 11. Cross section of portion of a leaf, showing resin gland. × 500. *t*, Epidermis, showing cuticle; *u*, resin gland; v, photosynthetic cells; *w*, water-storage cells; *x*, xylem of a vascular bundle.

FIG. 12. Tangential section of leaf, showing cross section of resin gland. × 500. *y*, Water-storage cells; *z*, photosynthetic cells; *a*, resin gland.

FIG. 13. Tangential section through the tip of the tooth on the margin of the leaf. × 500. *b*, Resin glands; *c*, tracheids; *d*, water-storage cells; *e*, tracheids; *f*, water-storage cells.

FIG. 14. Cross section through the tip of a tooth on the margin of the leaf. × 300. *g*, Resin glands; *h*, water-storage cells; *i*, tracheids; *j*, photosynthetic cells.

FIG. 15. Composite drawing of bleached leaf. × 500. *k*, Epidermal cells; *l*, veins; *m*, stoma; *n*, water-storage cells.

FIG. 16. Epidermis of leaf. × 500. *o*, Stoma; *p*, epidermis; *q*, photosynthetic cells.

FIG. 17. Photosynthetic cells. × 500. *t*, Nucleus; *s*, chloroplasts.

FIG. 18. Epidermis of leaf. × 500. *u*, Epidermal cell; *v*, stoma; *w*, guard cell.

FIG. 19. Epidermis of leaf. × 500. *x*, Epidermis; *y*, guard cell; *a*, cuticle on inner wall of guard cell.

FIG. 20. Tracheids from leaf. × 500. *b*, Spiral tracheids; *c*, pitted tracheids; *d*, tracheids with elongated pits.

PLATE V.

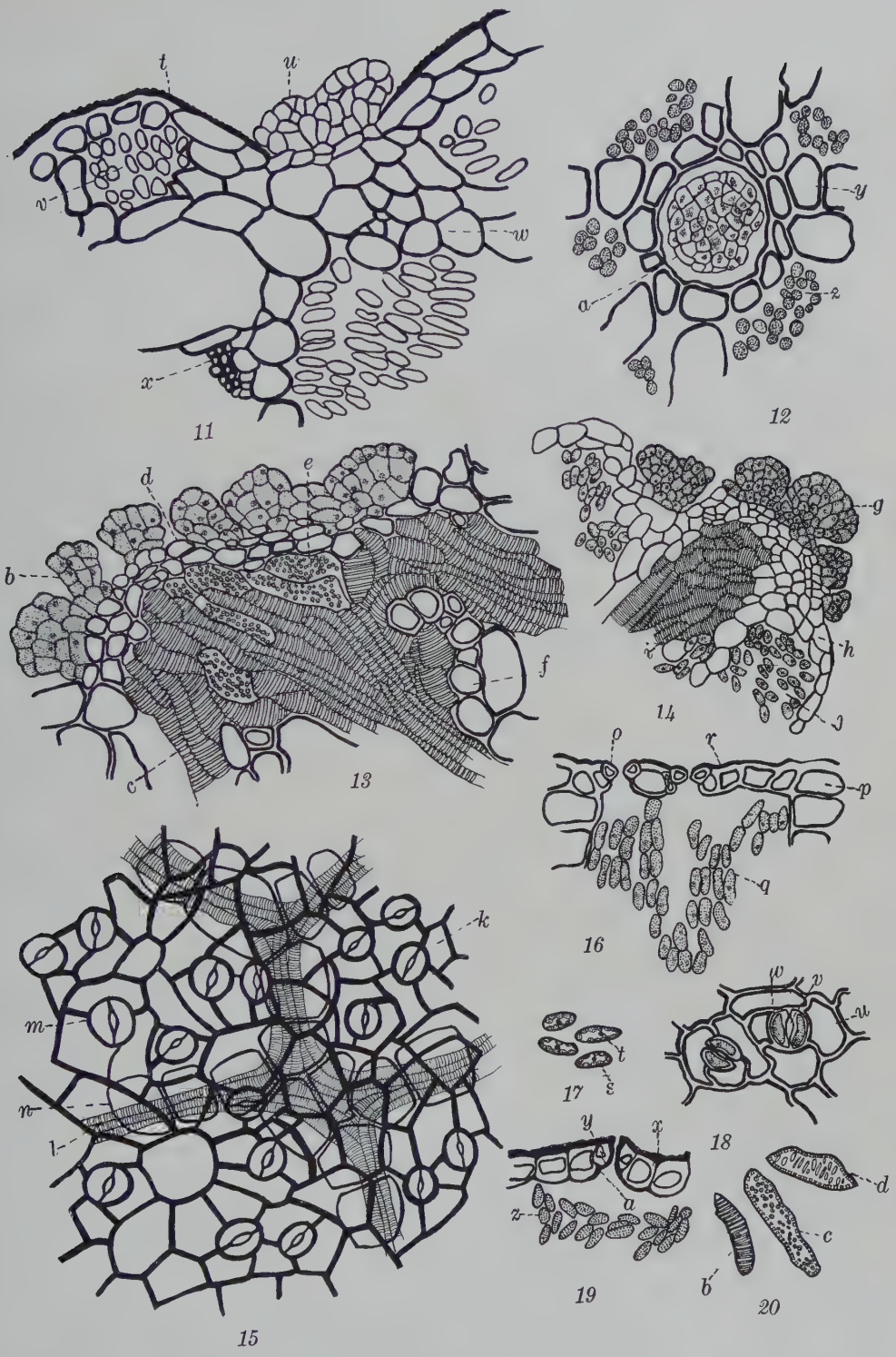
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PLATE VI.

FIG. 21. Protuberance on stem. × 500. *e*, Epidermis; *f*, collenchyma.

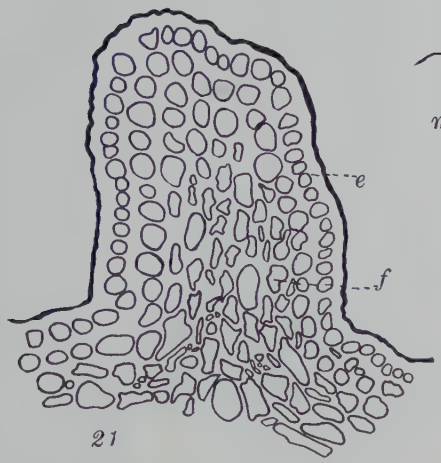
FIG. 22. Section of stem from epidermis to pith. × 500. *g*, Pith, *h*, tracheal vessel; *i*, phloem; *j*, wood fibers; *k*, starch sheath; *l*, epidermis; *m*, collenchyma; *n*, bast; *o*, parenchyma between bast groups.

FIG. 23. Longitudinal section of pith. × 500.

FIG. 24. Cross section of pith. × 500.

FIG. 25. Diagram of stem. × 70 *p*, Epidermis; *q* collenchyma; *r*, phloem; *s*, bast; *t*, xylem; *u*, pith.

PLATE VI.



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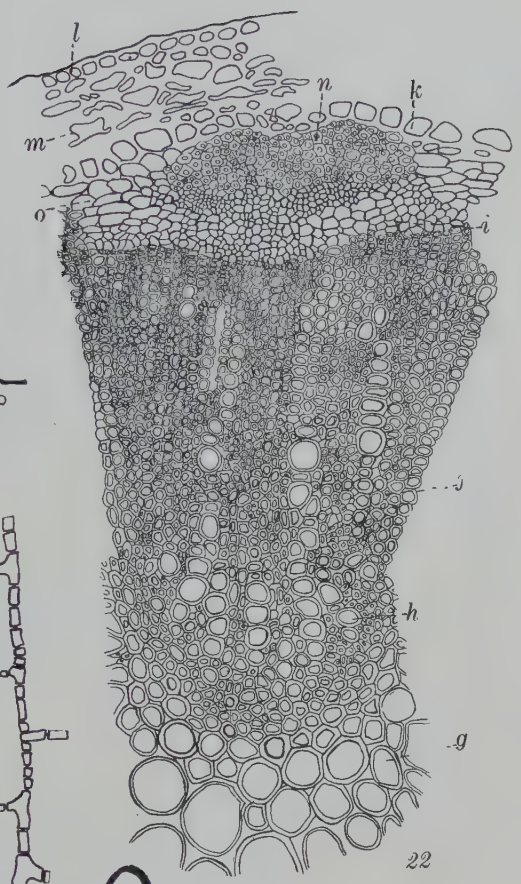

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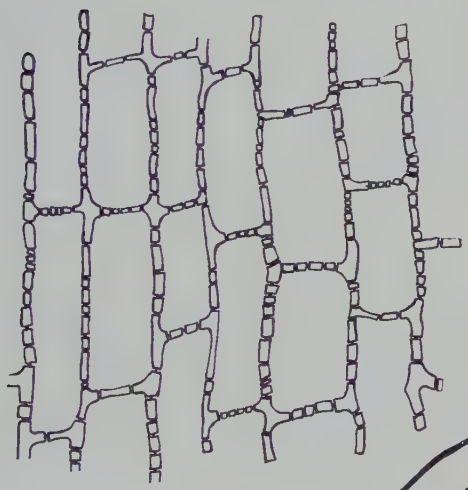

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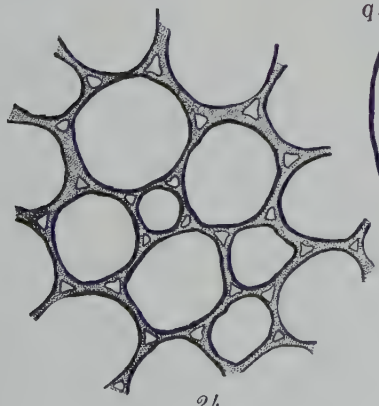

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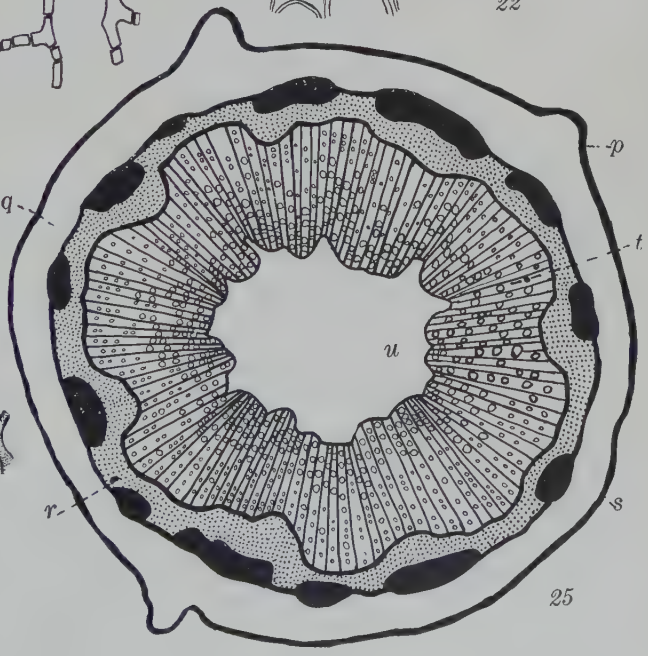

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PLATE VII.

FIG. 26. Base of vascular bundle. × 500. *v*, Wood fibers; *w*, tracheal tubes; *x*, lignified pith cells; *y*, xylem parenchyma.

FIG. 27. Medullary ray. × 500. *z*, Xylem; *a*, pith; *b*, medullary ray cells; *c*, cells resembling wood fibers.

FIG. 28. Cross section of portion of cortex from young stem. × 500. *d*, Cuticle; *e*, epidermis; *f*, collenchyma.

FIG. 29. Tracheal vessels. × 500. *g*, Pitted vessel; *h*, vessel with spiral thickenings.

FIG. 30. Cross section of phloem. × 500.

FIG. 31. Cross section of bast. × 500.

FIG. 32. Longitudinal section of wood fibers. × 500.

FIG. 33. Longitudinal section of wood parenchyma. × 500.

FIG. 34. Cross section of portion of cortex of old stem. × 500. *i*, Epidermis; *j*, collenchyma.

FIG. 35. Diagram of flower scale. × 120. *k*, Water-storage tissue; *l*, vein; *m*, photosynthetic tissue.

FIG. 36. Cross section of tissue separating two bast groups. × 580. *n*, Collenchyma; *o*, bast; *p*, starch sheath, showing portion not lignified; *q*, thin-walled cells separating bast groups.

FIG. 37. Longitudinal section through cortex. × 300. *r*, Epidermis; *t*, collenchyma; *s*, starch sheath.

PLATE VII.

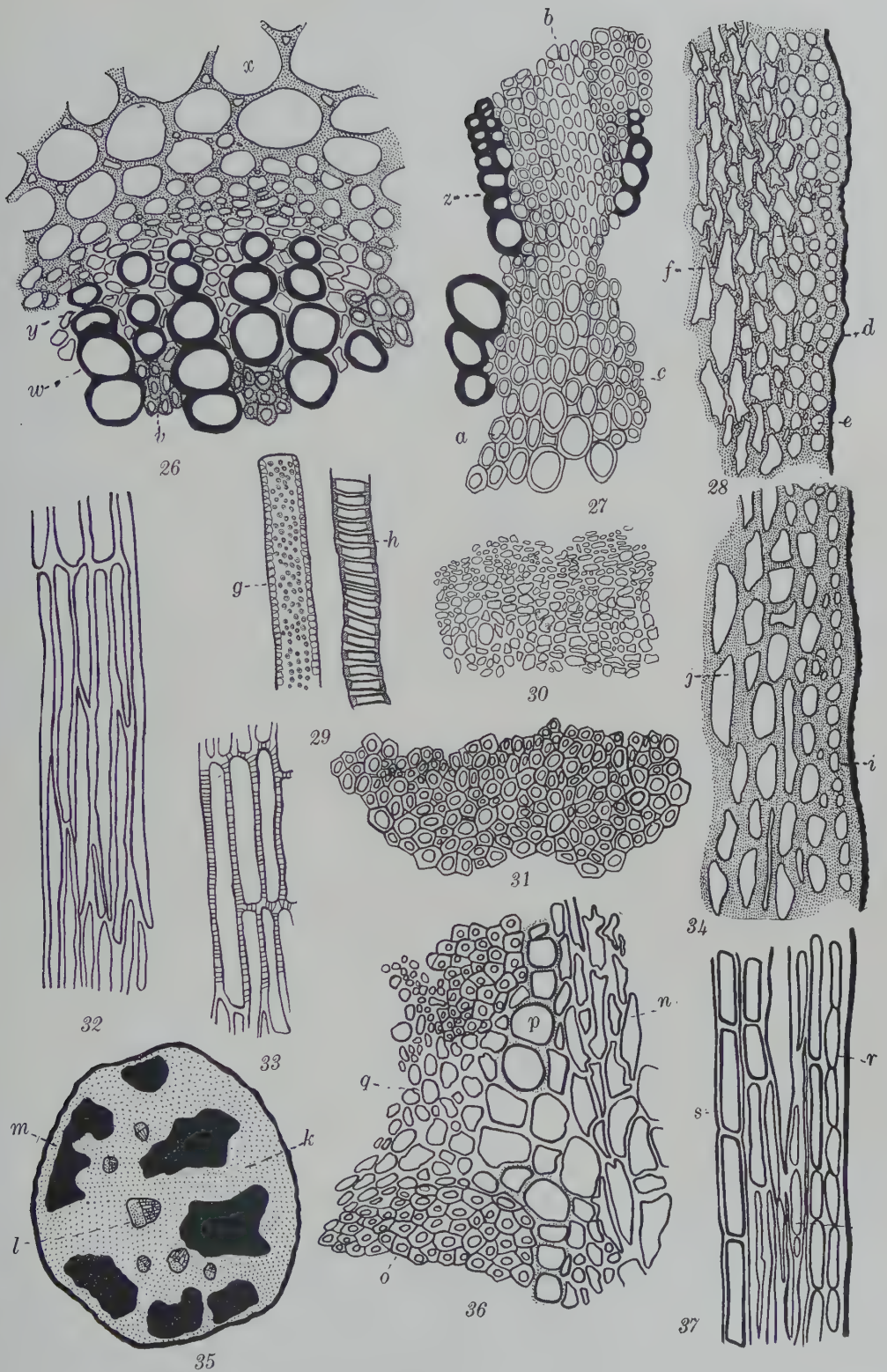

PLATE VIII.

FIG. 1. Typical leaf of No. 1, average size. × ½.

FIGS. 2 and 3. Prevailing types of leaves of No. 2. × ½.

FIGS. 4 and 5. Prevailing types of leaves of No. 3. × ½.

FIGS. 5 and 6. Prevailing types of leaves of No. 4. × ½.

FIG. 8. Acorn of No. 1. A, side view; B, front view; C, seed; D, longitudinal section through cup. × 1.

FIG. 9. Acorn of No. 2. A, side view; B, front view; C, seed; D, longitudinal section through cup. × 1.

FIG. 10. Acorn of No. 3. A, side view; B, end view; C, seed; D, longitudinal section through cup. × 1.

FIG. 11. Acorn of No. 4. A, side view; B, front view; C, seed; D, longitudinal section through cup. × 1.

FIG. 12. Section through shell of acorn of No. 1. × 22½.

FIG. 13. Section through shell of acorn of No. 2. × 22½.

FIG. 14. Section through shell of acorn of No. 3. × 22½.

FIG. 15. Section through shell of acorn of No. 4. × 22½.

PLATE VIII.

PLATE IX.

FIG. 16. Stoma of *Q. muhlenbergii* (semidiagrammatical). Dotted line shows position of inner cell wall when cell is turgid. (p′, r′.)

FIG. 17. Longitudinal section of guard cell along line a-b, fig. 16.

FIG. 18. Cross section of stoma along line m-n, fig. 16. r-r′ shows movement in opening.

FIG. 19. Cross section of stoma along line x-y, fig. 16. p-p′ shows movement due to turgidity.

FIG. 20. Lower epidermis of leaf of *Q. rubra* about 2 days old, showing type and frequency of stomata. (Heavy lines.) × 405.

FIG. 21. Lower epidermis of leaf of *Q. rubra* about 7 days old, showing development of stomata. Same area as fig. 20. × 405.

FIG. 22. Lower epidermis of leaf of *Q. rubra* at maturity, showing type and frequency of stomata. Same area as figs. 20 and 21. × 405.

FIG. 23. Frequency of stomata on leaves of No. 1. 1 sq. mm. × 67. Black square in lower corner is 1 sq. mm.

FIG. 24. Frequency of stomata on leaves of No. 2. 1 sq. mm. of leaf surface. × 67.

FIG. 25. Frequency of stomata on 1 sq. mm. of leaf surface of No. 3. × 67.

PLATE IX.

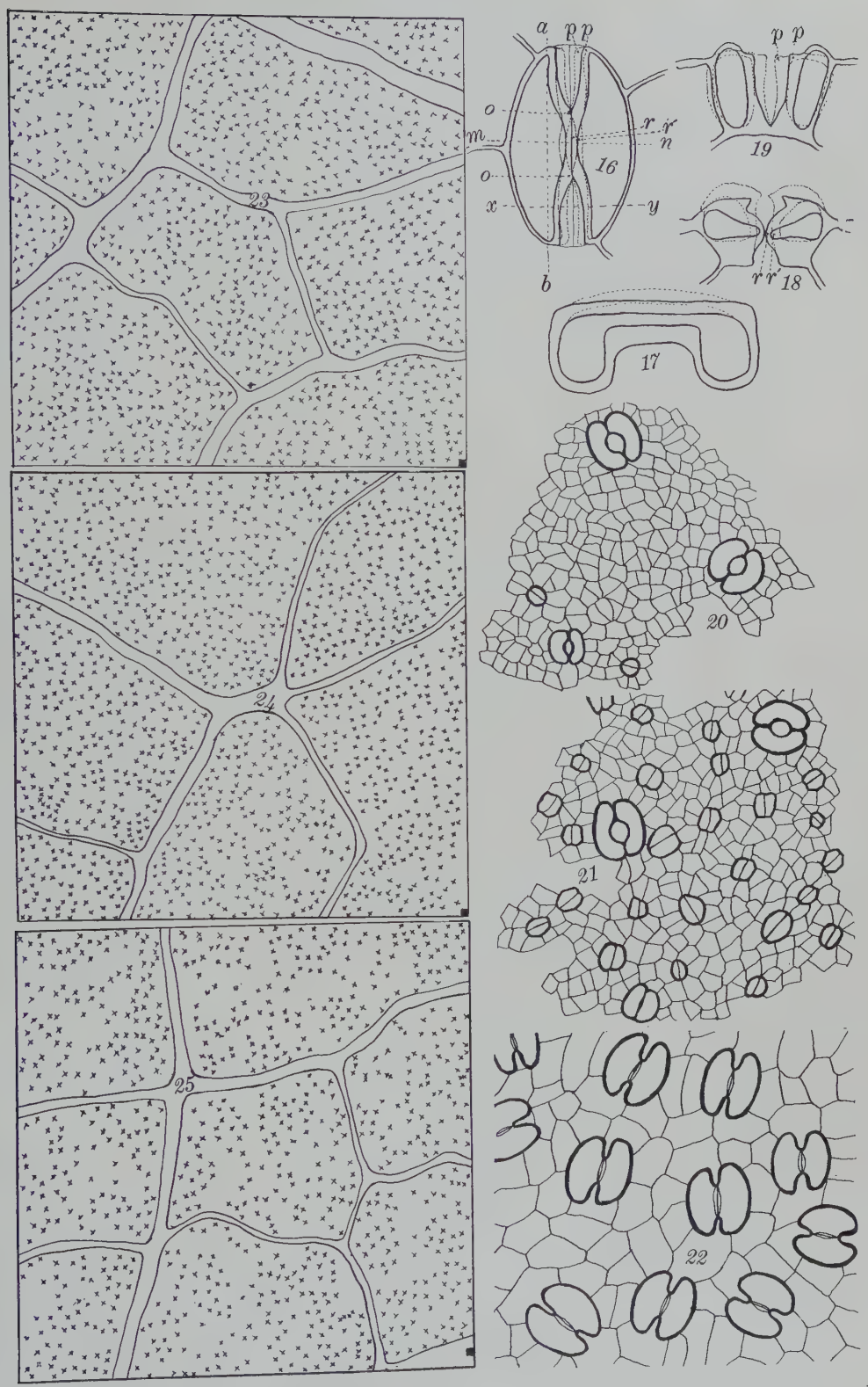

PLATE X.

FIG. 26. Frequency of stomata on 1 sq. mm. of leaf surface of No. 4. × 67.

FIG. 27. Cross section of midrib, No. 1 ⅔ length of leaf from base of blade. Bast stippled; phloem, black; xylem showing water tubes. × 23.

FIG. 28. Cross section of midrib, No. 2, same position as in No. 1 (fig. 27), showing persistence of middle bundle. × 23.

FIG. 29. Cross section of midrib of No. 3, same position as in No. 1 (fig. 27).

FIG. 30. Cross section of midrib of No. 4, same position as in No. 1 (fig. 27).

FIG. 31. Showing manner of ending of middle vascular bundle of midrib in Nos. 1, 2, and 3; e, position of bundles immediately above junction with vein; f, toii, stages in joining of middle bundle with upper bundle. Bast, stippled; phloem, black; xylem, showing water tubes (diagramatical).

FIG. 32. Modification of ending shown in fig. 31, also found in Nos. 1, 2, and 3.

FIG. 33. Showing manner of ending of middle bundle of midrib in No. 4. Middle bundle joining upper bundle at side.

FIG. 34. Cross section of petiole at base of blade, No. 1. Bast, stippled; phloem, black; xylem, showing water tubes; k, middle vascular bundle.

FIG. 35. Cross section of petiole of No. 2 at base of blade. × 23.

FIG. 36. Cross section of petiole of No. 3 at base of blade. × 23.

FIG. 37. Cross section of petiole of No. 4 at base of blade. × 23.

FIG. 38. Cells from seed of No. 1, showing starch grains. × 255.

FIG. 39. Cells from seed of No. 2, showing starch grains. × 255.

FIG. 40. Cells from seed of No. 3, showing starch grains. × 255.

FIG. 41. Cells from seed of No. 4, showing starch grains. × 255.

FIG. 42. Stone cells, acorn cup.

FIG. 43. Tracheids, acorn cup.

FIG. 44. Stone cells from shell of acorn.

PLATE X.

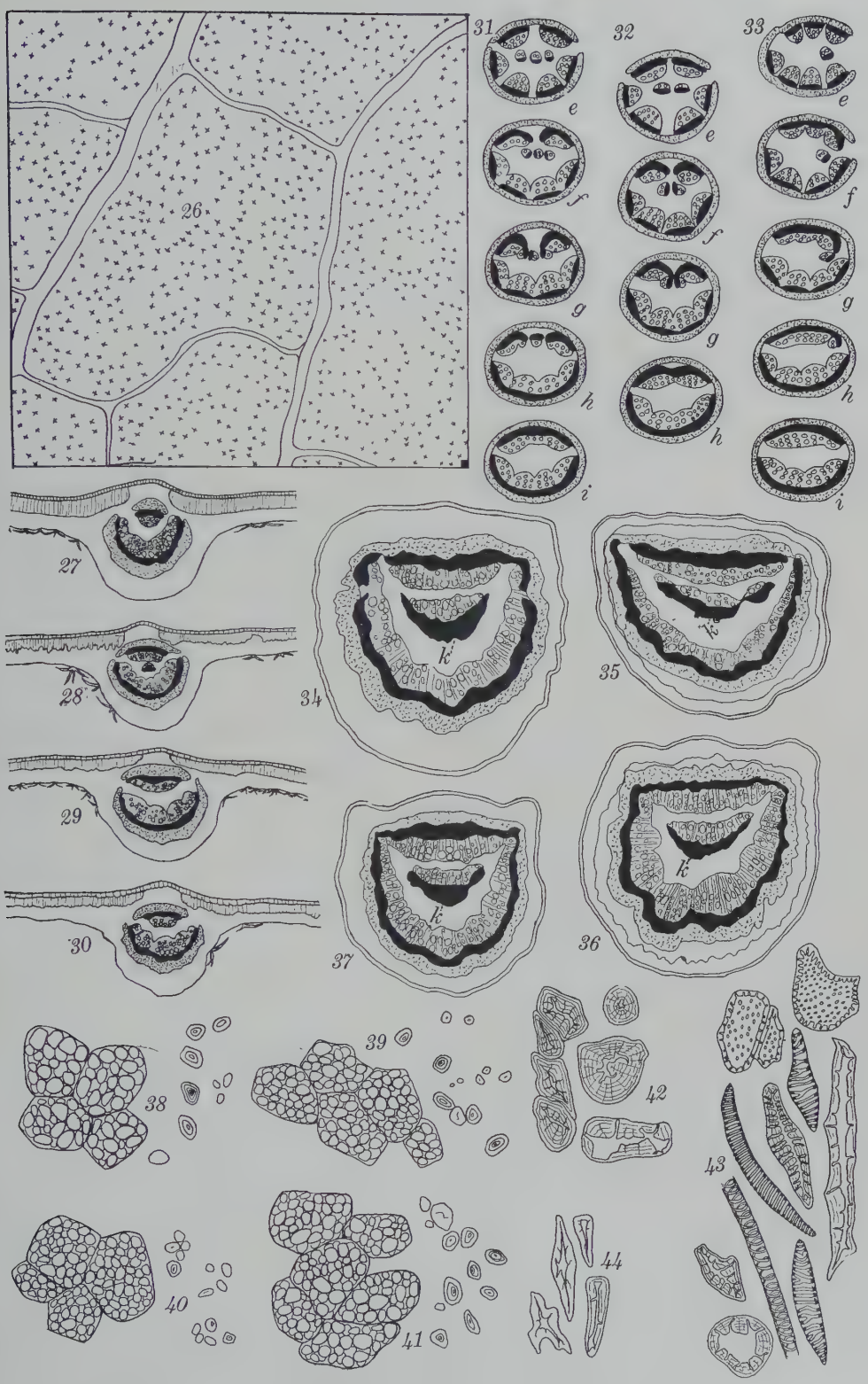
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PLATE XI.

FIG. 45. Tissues of the leaf of No. 1, from bleached leaf. A, upper epidermis; B, palisade cells; C, spongy parenchyma; D, lower epidermis with stomata; E, epidermal hairs; z, crystal of calcium oxylate. × 275.

FIG. 46. Tissues of the leaf of No. 2, from bleached leaf. A, B, C, D, and E, same as in fig. 45. × 275.

FIG. 47. Tissues of the leaf of No. 3, from bleached leaf. A, B, C, D, and E, same as in fig. 45. × 275.

FIG. 48. Tissues of the leaf of No. 4, from bleached leaf. A, B, C, D, and E, same as in fig. 45. × 275.

PLATE XI.

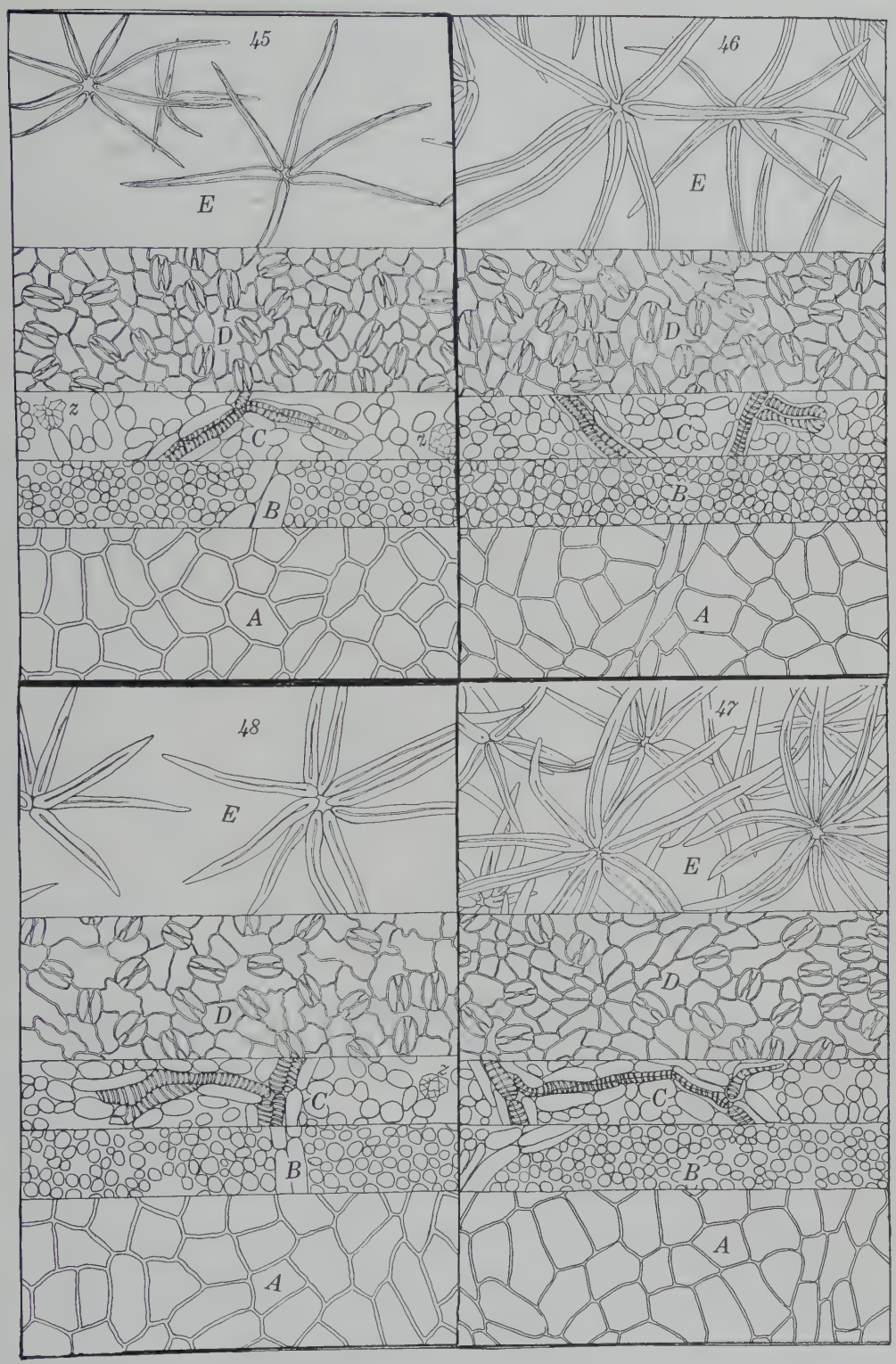


PLATE XII.

FIG. 49. Venation of leaf of No. 1. × 55.
FIG. 50. Venation of leaf of No. 2. × 55.
FIG. 51. Venation of leaf of No. 3. × 55.
FIG. 52. Venation of leaf of No. 4. × 55.

PLATE XII.

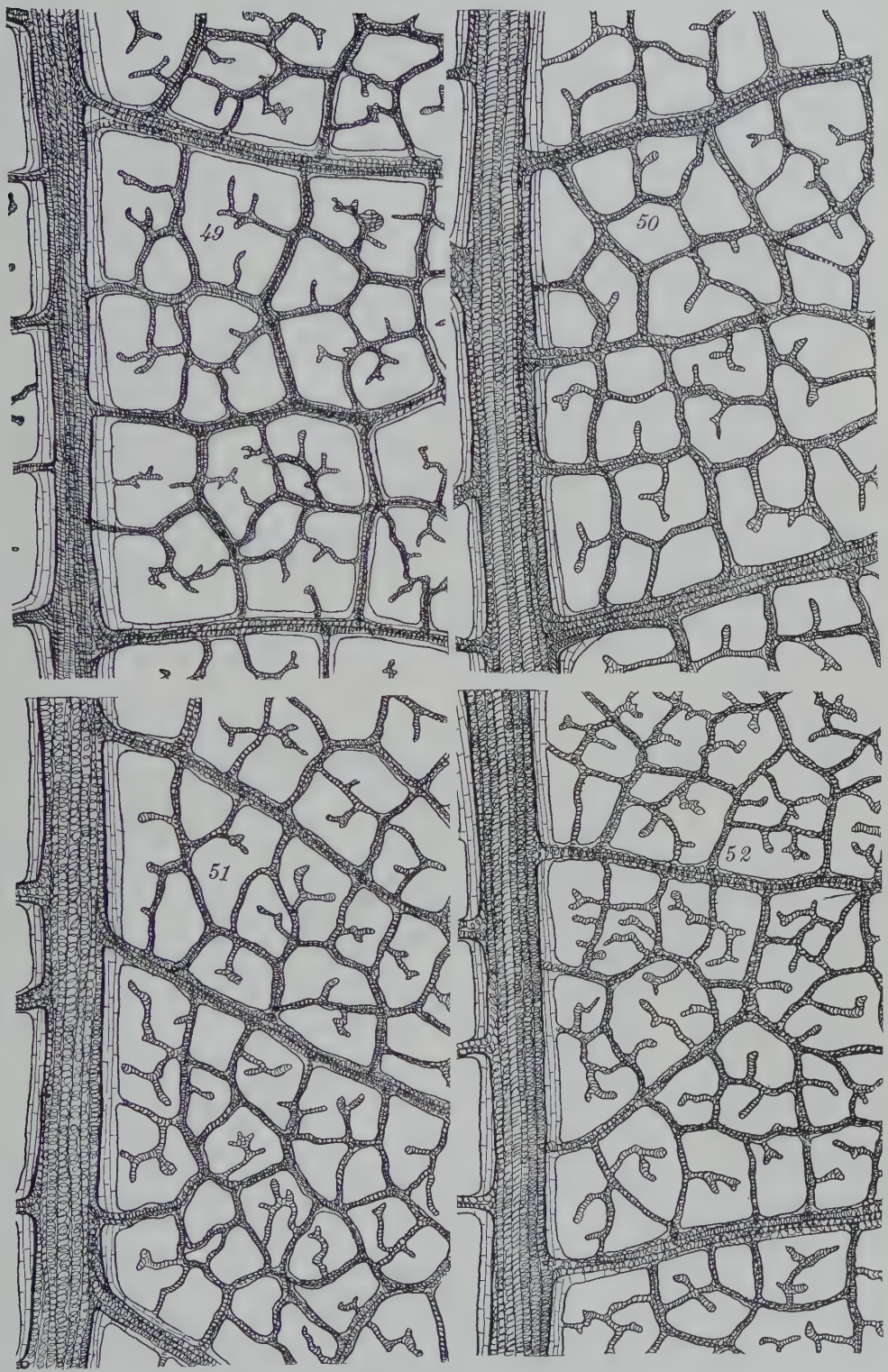


PLATE XIII.

FIG. 53. Cross section of stem of No. 1, current year; v, pith; w, xylem; x, pholem; y, bast. × 23.

FIG. 54. Cross section of stem of No. 2, current year; v, w, x, y, same as in Fig. 53. × 23.

FIG. 55. Cross section of stem of No. 3, current year; v, w, x, y, same as in Fig. 53. × 23.

FIG. 56. Cross section of stem of No. 4, current year; v, w, x, y, same as in Fig. 53. × 23.

FIG. 57. Tangential section of wood, showing size and frequency of medullary rays, No. 1. × 53.

FIG. 58. Tangential section of wood, No. 2. × 53.

FIG. 59. Tangential section of wood, No. 3. × 53.

FIG. 60. Tangential section of wood, No. 4. × 53.

PLATE XIII.

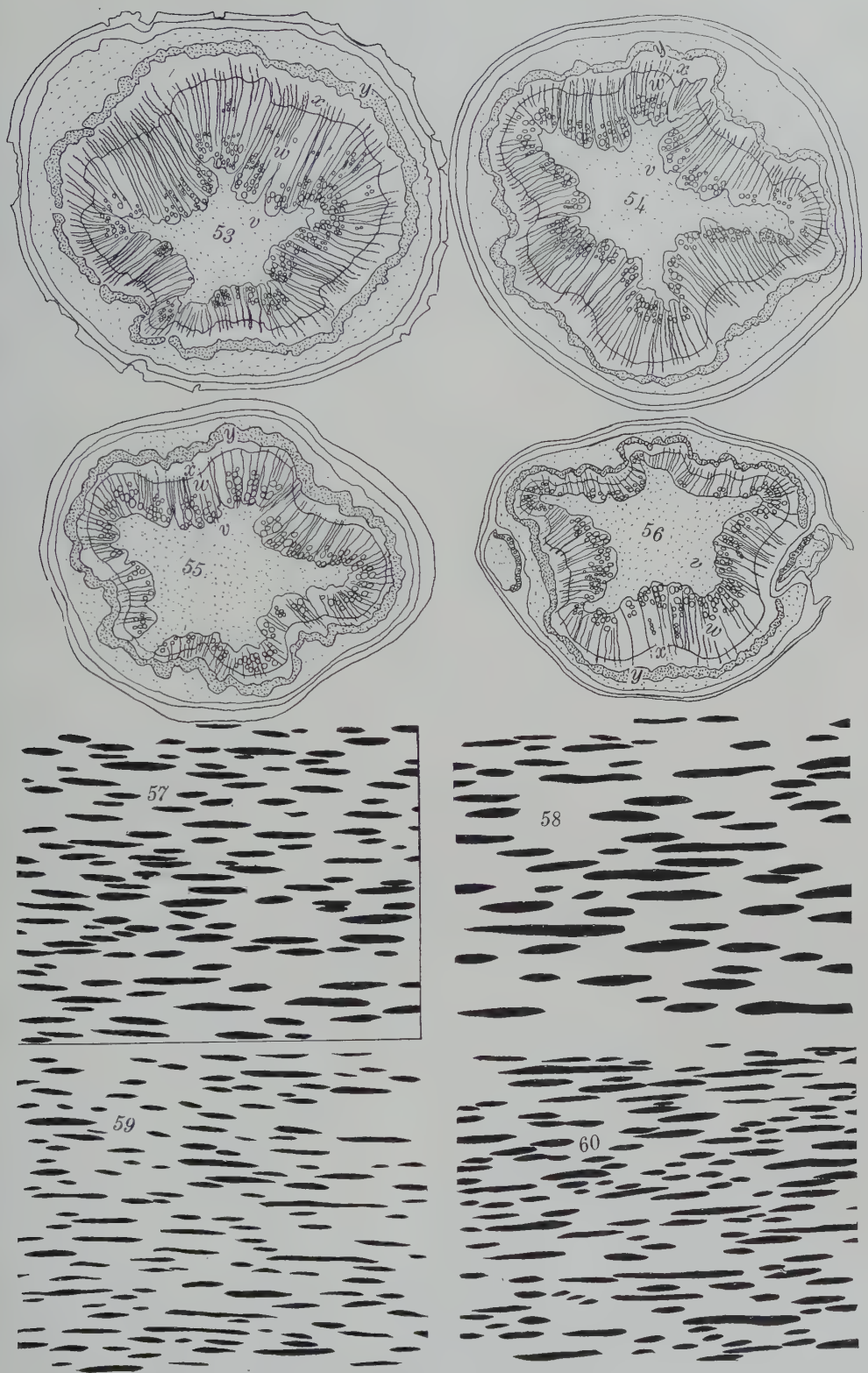


PLATE XIV.

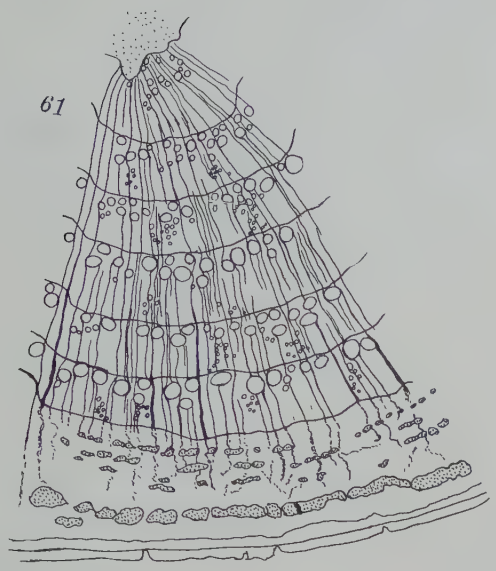
FIG. 61. Cross section of stem, No. 1, in sixth year, showing rings of growth, tracheal tubes, medullary rays, and bark. Bast stipuled. × 23.

FIG. 62. Cross section of stem, No. 2, in seventh year, showing same elements as fig. 61. × 23.

FIG. 63. Cross section of stem, No. 3, in fourth year, showing same elements as fig. 61. × 23.

FIG. 64. Cross section of stem, No. 4, in third year, showing same elements as fig. 61. × 23.

PLATE XIV.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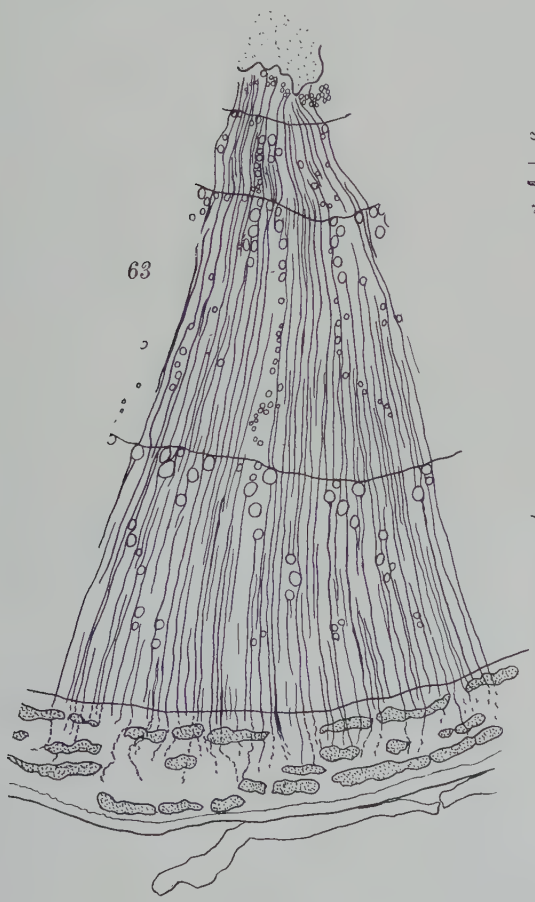

63

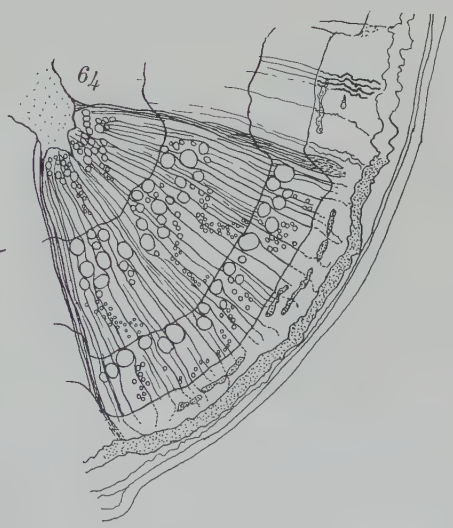

64

PLATE XV.

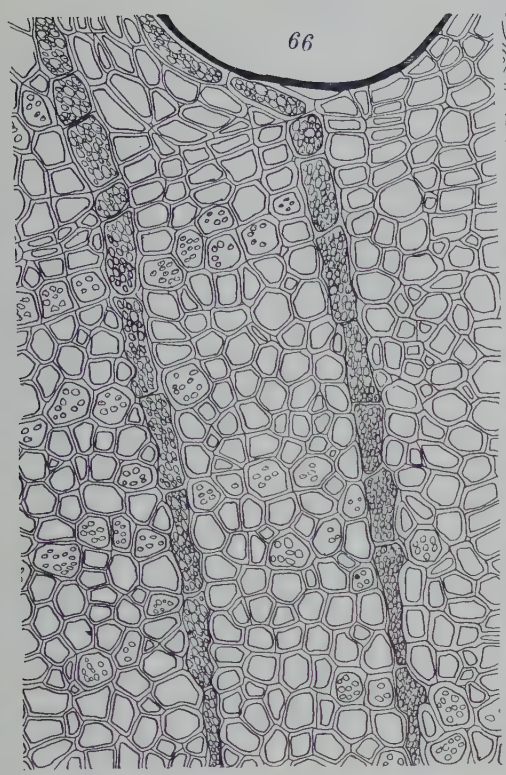
FIG. 65. Cross section of wood, No. 1, in fourth year, showing wood fiber, medullary rays, and part of cross section of tracheal tube. (Heavy wall.) × 275.

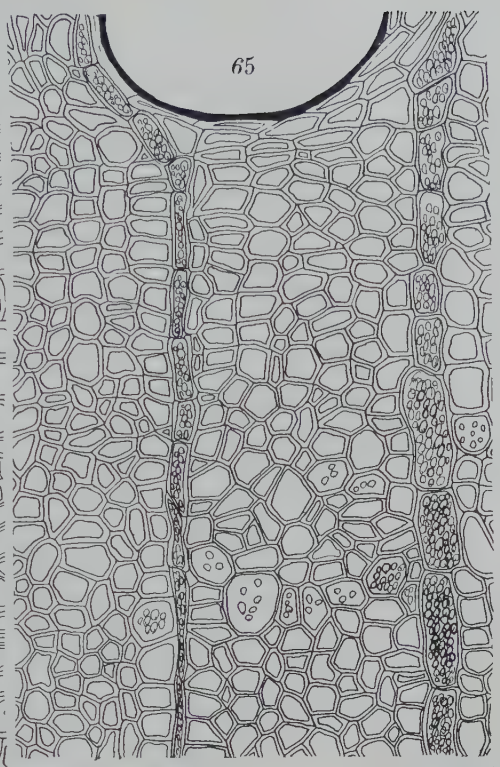
FIG. 66. Cross section of wood, No. 2, in fourth year. × 275.

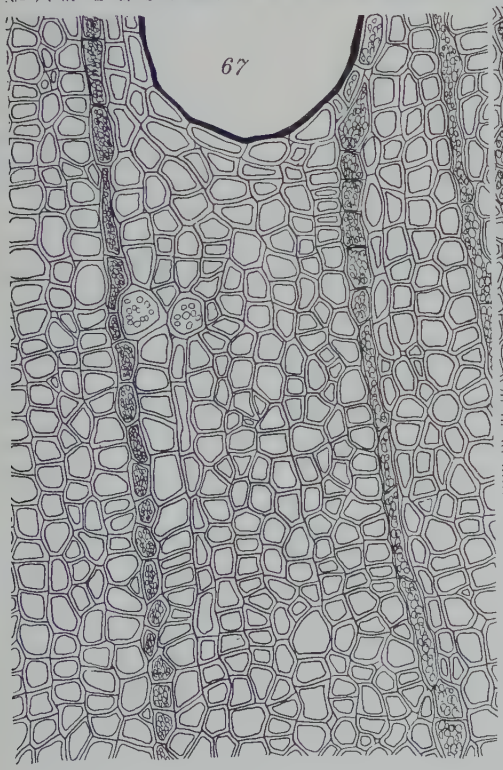
FIG. 67. Cross section of wood, No. 3, in fourth year. × 275.

FIG. 68. Cross section of wood, No. 4, in third year. × 275.

PLATE XV.







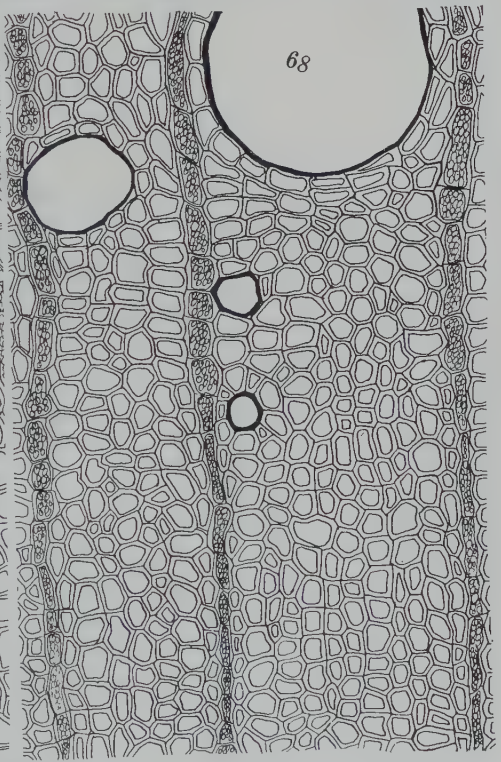


PLATE XVI.

FIG. 1. Tangential section of leaf of *X. pennsylvanicum.* × 200. *A*, border parenchyma cells; *B*, tracheal vessels; *C*, photosynthetic tissue.

FIG. 2. Tangential section of leaf of *X. globosum.* × 200. *D*, border parenchyma cells; *E*, tracheal vessels, *F*, photosynthetic tissue.

FIG. 3. Tangential section of leaf of *X. americanum.* × 200. *C*, border parenchyma cells; *H*, tracheal vessels; *I*, photosynthetic tissue.

FIG. 4. Cross section of leaf of *X. americanum.* × 193. *J*, epidermis; *K*, tracheal vessels; *L*, border parenchyma cells; *M*, photosynthetic cells; *N*, vascular bundle; *O*, trichome.

FIG. 5. Photosynthetic cells from the leaf of *X. pennsylvanicum.* × 193.

FIG. 6. Smaller photosynthetic cells from the leaf of *X. pennsylvanicum.* × 193.

FIG. 7. Photosynthetic cells from the leaf of *X. Globosum.* × 193.

FIG. 8. Photosynthetic cells from the leaf of *X. americanum.* × 193.

FIG. 9. Cross section of leaf of *X. pennsylvanicum.* × 193. *P*, stoma; *Q*, epidermis; *R*, vessels; *S*, water-storage cells; *T*, vascular bundle; *U*, trichome from leaf.

PLATE XVI.

PLATE XVII.

FIG. 10. Apex of bleached leaf of *X. globosum* showing serration. × 11. *W*, clusters of tracheids; *X*, hairs from leaf.

FIG. 11. Cross section of midrib of leaf of *X. globosum.* × 27. *A*, photosynthetic tissue; *B*, water-storage cells; *C*, collenchyma of midrib; *D*, epidermis; *X*, xylem of vascular bundle; *Y*, phloëm.

FIG. 12. Cross section at the base of leaf of *X. pennsylvanicum.* × 17. *E*, vasular bundle; *F*, collenchyma; *G*, resin duct; *H*, photosynthetic cells; *I*, water-storage cells; *J*, midrib of leaf.

FIG. 13. Tracheids from leaf of *X. globosum.* × 193.

FIG. 14. Stomata from leaf of *X. globosum.* × 193. *K*, epidermal cells; *L*, photosynthetic cells; *M*, stoma.

FIG. 15. Epidermis of midrib of leaf of *X. pennsylvanicum.* × 200. *N*, epidermis.

FIG. 16. Tangential section of epidermis from the bleached leaf of *X. globosum.* × 200. *O*, stoma.

FIG. 17. Tangential section of epidermis of the leaf of *X. americanum.* × 193. *Q*, cells at base of hairs; *R*, stoma; *S*, epidermal cells.

FIG. 18. Trichomes on leaf of *X. americanum.* × 193. *T*, cells at base of hairs.

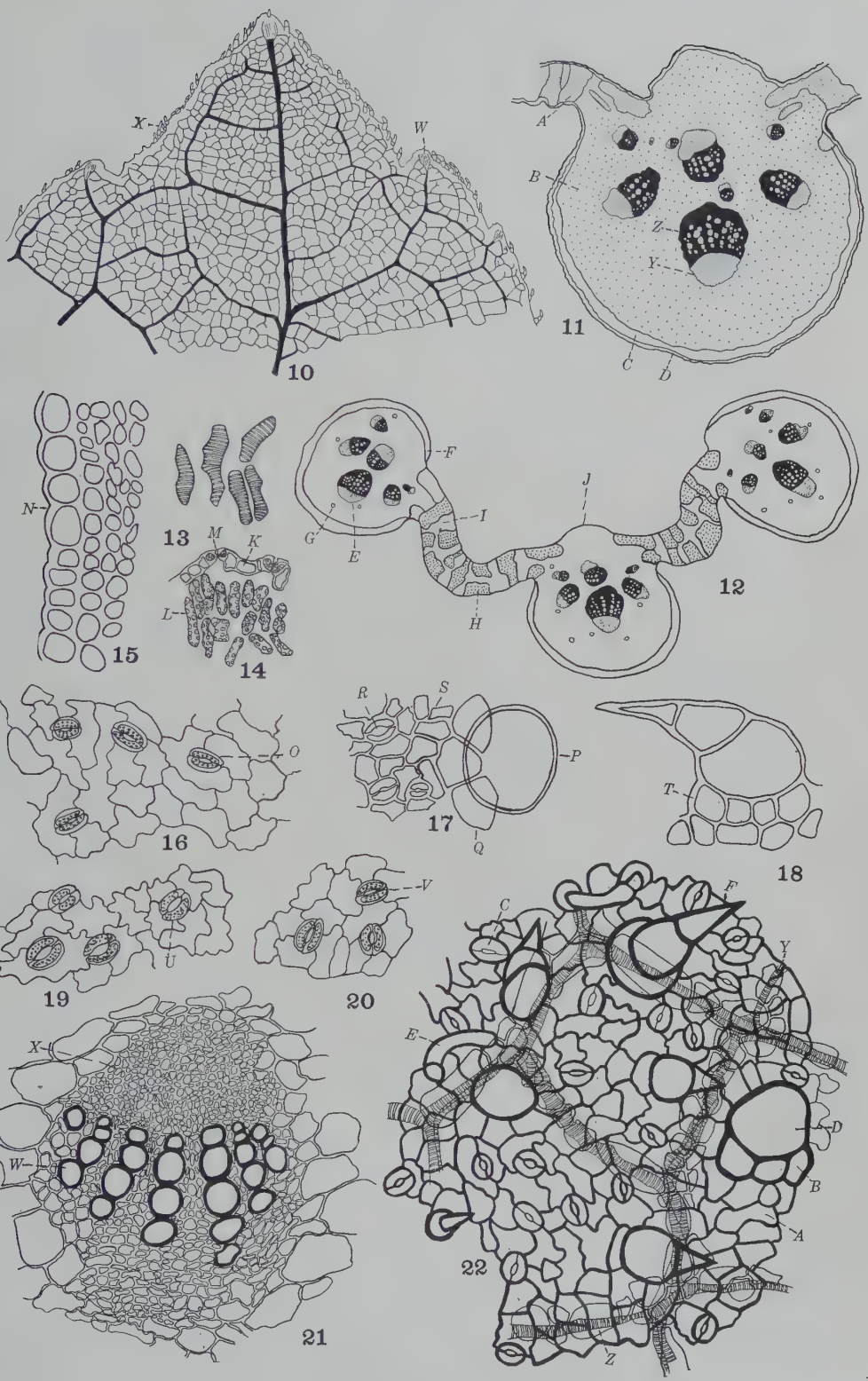
FIG. 19. Tangential section from bleached leaf of *X. pennsylvanicum.* × 200. *U*, stoma.

FIG. 20. Tangential section from bleached leaf of *X. americanum.* × 200. *V*, stoma.

FIG. 21. Central vascular bundle from leaf of *X. pennsylvanicum,* × 127. *W*, vessels; *X*, phloëm.

FIG. 22. Composite drawing of leaf of *X. globosum.* × 193. *Y*, vessels; *Z*, border parenchyma; *A*, epidermal cells; *B*, cells at base of hairs; *C*, stoma; *D*, basal cell of hair; *E*, linear hair; *F*, pointed hairs.

PLATE XVII.


X
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A
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Y
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11
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X
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Z

PLATE XVIII.

FIG. 23. Tangential section of bleached leaf of *X. globosum,* showing relation of trichomes to veins. × 43. *G,* veins; *H,* trichome.

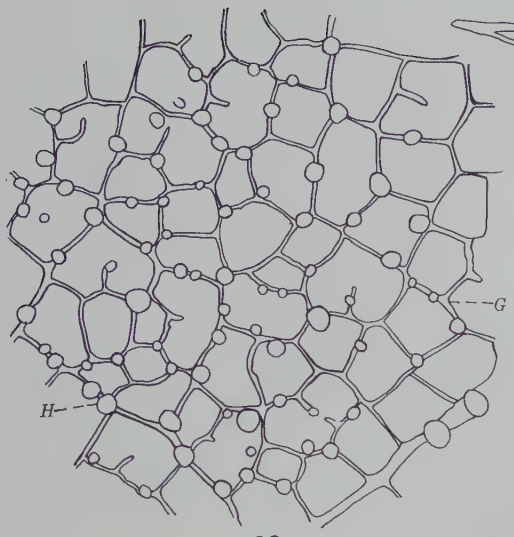
FIG. 24. Large trichomes from leaf of *X. americanum.* × 193. *I,* cells at base of hairs; *J,* stoma; *K,* epidermal cells; *L,* basal cell of hairs.

FIG. 25. Diagram of cross section of stem of *X. americanum.* × 11. *M,* collenchyma; *N,* resin duct; *O,* bast; *P,* phloëm; *Q,* xylem; *R,* pith; *S,* parenchyma of pericycle.

FIG. 26. Diagram of cross section of stem of *X. pennsylvanicum.* × 11. *T,* collenchyma; *U,* parenchyma of pericycle; *V,* resin duct; *W,* bast, *X,* phloëm; *Y,* xylem; *Z,* pith.

FIG. 27. Diagram of cross section of stem of *X. globosum.* × 11. *A,* epidermis; *B,* collenchyma; *C,* parenchyma of pericycle; *D,* resin duct; *E,* bast; *F,* phloëm, *G,* xylem.

PLATE XVIII.



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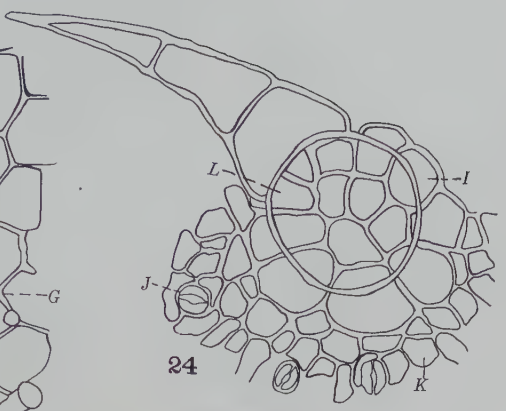

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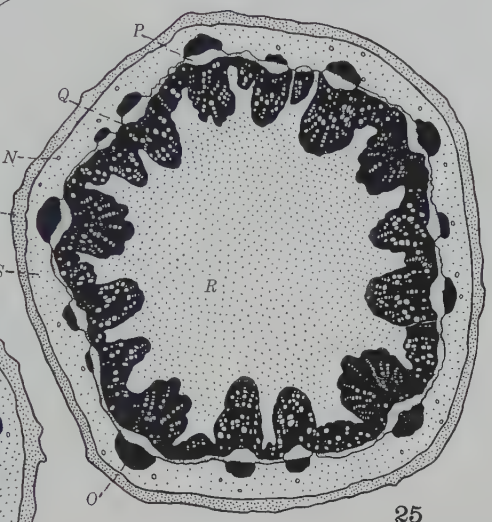

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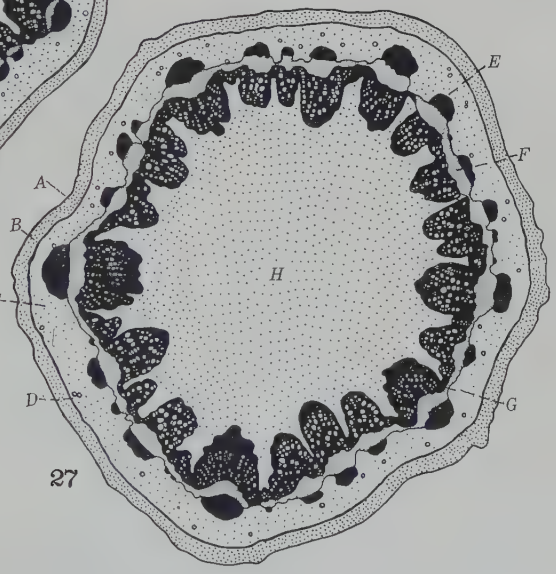

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PLATE XIX.

FIG. 28. Large vascular bundle at angle of stem of X. *globosum*. × 193. *I*, tracheal tube; *J*, parenchyma; *K*, bast; *L*, phloëm; *M*, wood parenchyma.

FIG. 29. Cross section of pith of stem of *X. pennsylvanicum*. × 133.

FIG. 30. Cross section of pith of stem of *X. americanum*. × 133.

FIG. 31. Cross section of pith of stem of *X. globosum*. × 133.

FIG. 32. Cross section of pith of *X. pennsylvanicum*, showing calcium oxalate crystals. × 193. *N*, calcium oxalate crystals.

FIG. 33. Longitudinal section of pith of *X. globosum*. × 193. *O*, calcium oxalate crystals.

FIG. 34. Cross section of phloëm from the stem of *X. pennsylvanicum*. × 133.

FIG. 35. Cross section of starch sheath from stem of *X. globosum*. × 193. *P*, calcium oxalate crystals; *Q*, starch grains; *R*, starch sheath.

FIG. 36. Cross section of starch sheath from the stem of *X. americanum*. × 193. *S*, starch sheath; *T*, starch grains; *U*, calcium oxalate crystals.

FIG. 37. Cross section of the starch sheath from the stem of *X. globosum*. × 193. *V*, starch sheath; *W*, starch grains; *X*, calcium oxalate crystals.

PLATE XIX.

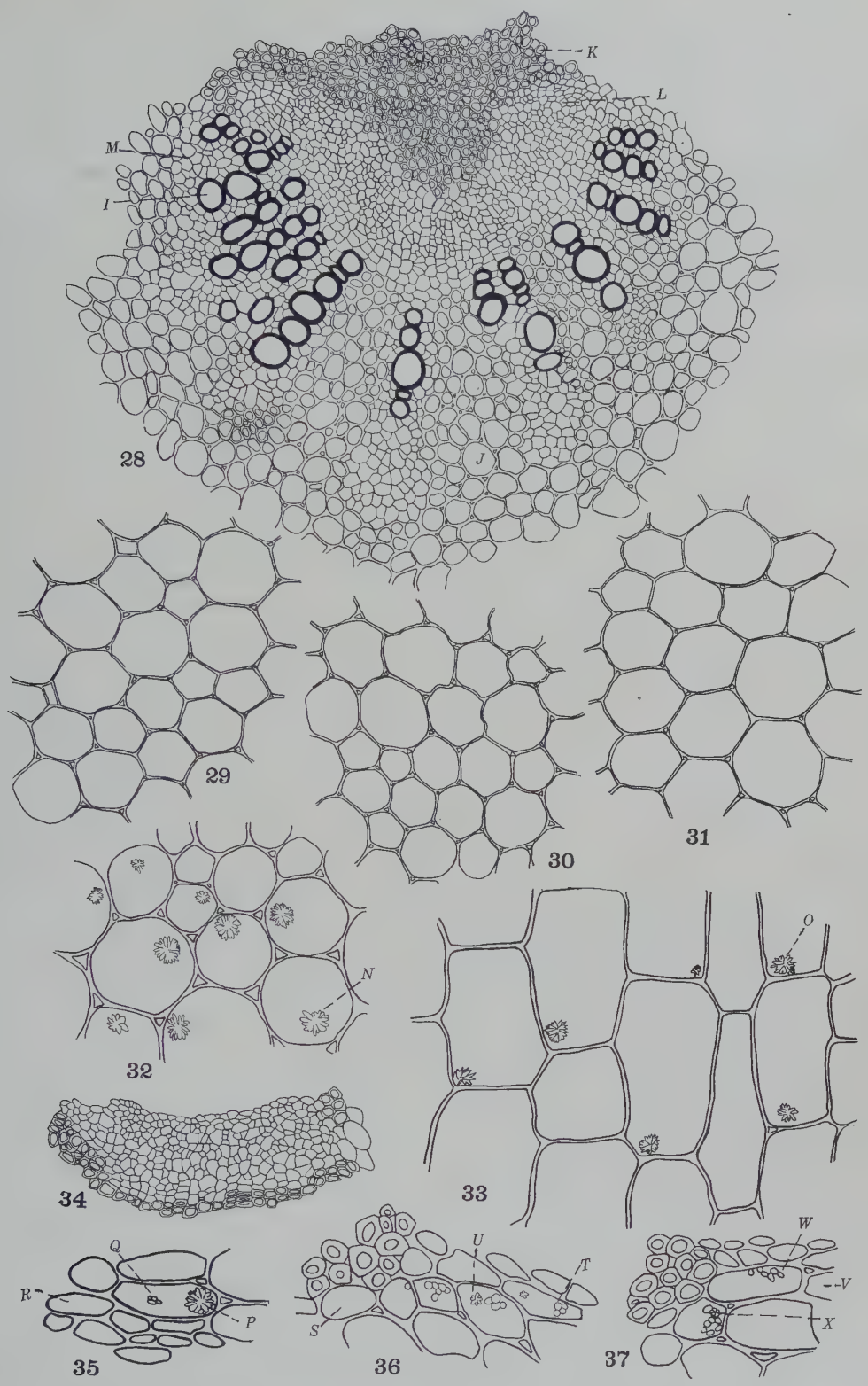


PLATE XX.

FIG. 38. Vascular bundle from the stem of *X. pennsylvanicum.* × 140. *A*, wood fibers; *B*, phloëm; *C*, bast; *Y*, tracheal vessels; *Z*, wood parenchyma.

FIG. 39. Vascular bundle from the stem of *X. americanum.* ×133. *D*, tracheal vessel; *E*, wood fibers; *F*, wood parenchyma; *G*, phloëm; *H*, bast.

FIG. 40. Vascular bundle from the stem of *X. globosum.* × 140. *I*, tracheal vessels; *J*, wood parenchyma; *K*, wood fibers; *L*, phloëm; *M*, bast.

FIG. 41. Cross section of portion of two bundles of stem of *X. globosum.* × 43. *N*, elongated ray cells.

FIG. 42. Cross section of base of bundle of *X. americanum.* × 193. *O*, tracheal vessel; *P*, lignified cells.

FIG. 43. Longitudinal section of wood parenchyma from *X. globosum.* × 193.

FIG. 44. Wood fibers from *X. globosum.* × 193.

FIG. 45. Tracheal elements in stem of *X. pennsylvanicum.* × 200.

FIG. 46. Tracheal elements in stem of *X. globosum.* × 200.

FIG. 47. Tracheal elements in stem of *X. americanum.* × 200.

FIG. 48. Wood fibers from *X. americanum.* × 193.

PLATE XX.

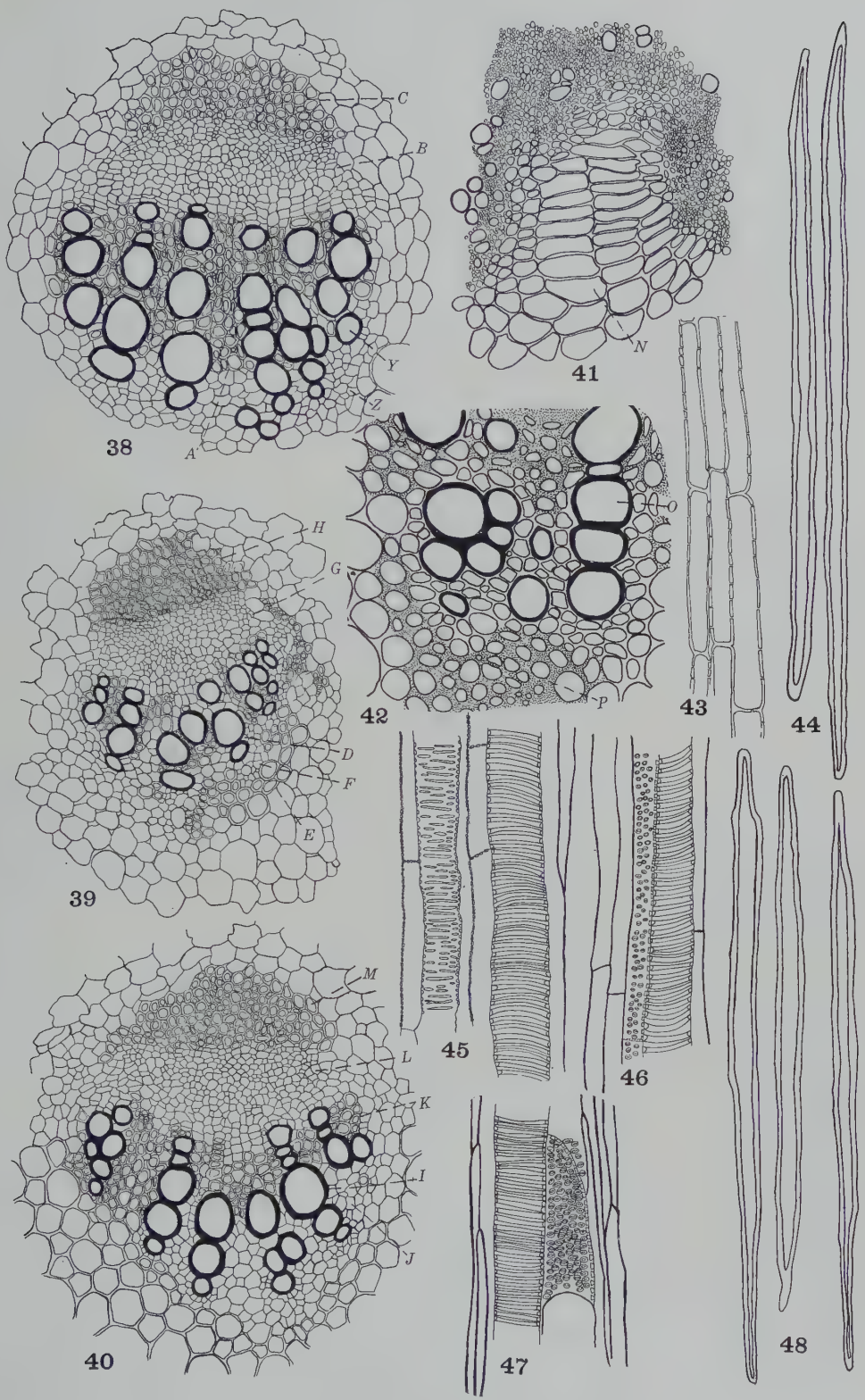


PLATE XXI.

FIG. 49. Cross section of portion of cortex of *X. pennsylvanicum.* × 200. *Q*, epidermis; *R*, collenchyma; *S*, parenchyma of pericycle; *T*, resin duct.

FIG. 50. Cross section of portion of cortex of *X. globosum.* × 200. *U*, epidermis; *V*, collenchyma; *W*, parenchyma of pericycle; *X*, resin duct.

FIG. 51. Longitudinal section of parenchyma of pericycle of *X. globosum.* × 193.

FIG. 52. Cross section of parenchyma of pericycle of *X. globosum.* × 193.

FIG. 53. Cross section of parenchyma of pericycle of *X. globosum*, showing resin duct. × 193. *Y*, parenchyma; *L*, resin duct.

FIG. 54. Trichome from surface of stem of *X. globosum.* × 193. *A*, epidermis; *B*, trichome.

FIG. 55. Tangential section of epidermis of stem of *X. globosum.* × 193. *C*, epidermal cell; *D*, glucosides.

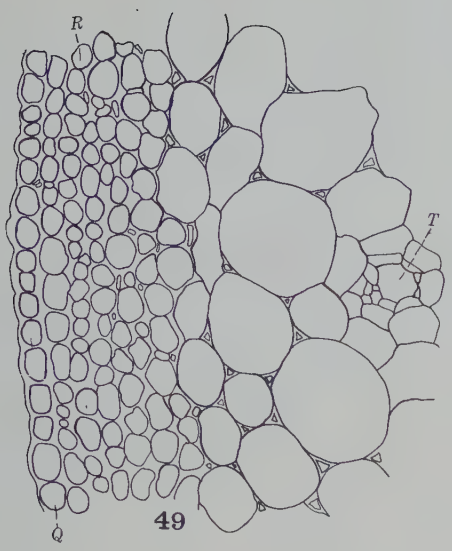
FIG. 56. Tangential section of epidermis of stem of *X. americanum.* × 193. *E*, epidermis; *F*, glucosides.

FIG. 57. Cross section of epidermis of *X. americanum.* × 193.

FIG. 58. Cross section of epidermis of *X. pennsylvanicum.* × 193.

FIG 59. Longitudinal section of epidermis of stem of *X. pennsylvanicum.* × 193.

PLATE XXI.



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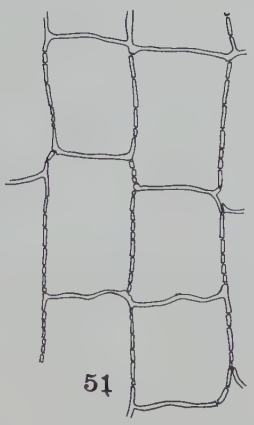

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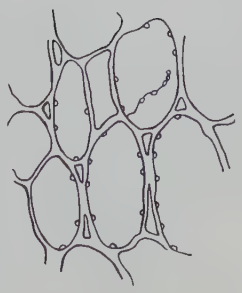

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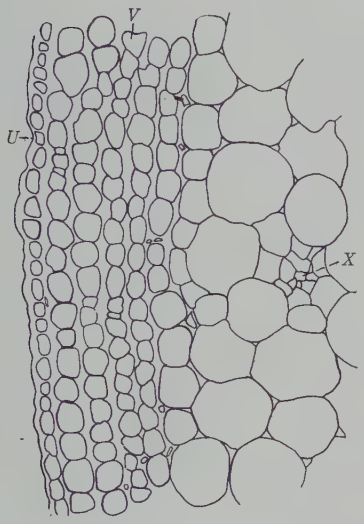

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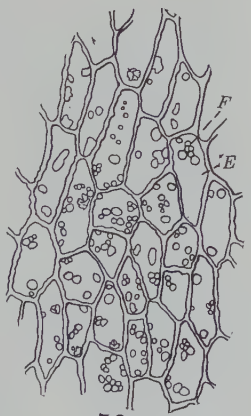

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PLATE XXII.

FIG. 60. Cross section of root of *X. globosum.* × 17. *G*, bark; *H*, phloëm; *I*, resin duct; *J*, medullary ray; *K*, tracheal tube.

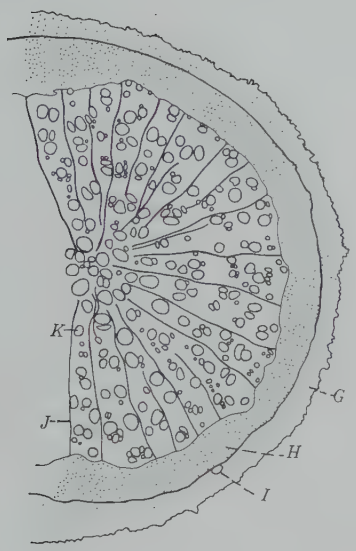
FIG. 61. Cross section of root of *X. pennsylvanicum.* × 17. *L*, bark; *M*, phloëm; *N*, resin duct; *O*, medullary ray; *P*, tracheal tube.

FIG. 62. Cross section of bast of *X. pennsylvanicum.* × 193. *Q*, starch sheath; *R*, bast.

FIG. 63. Cross section of bast of *X. globosum.* × 193. *S*, starch sheath; *T*, bast.

FIG. 64. Longitudinal section of bast of *X. globosum.* × 193.

PLATE XXII.



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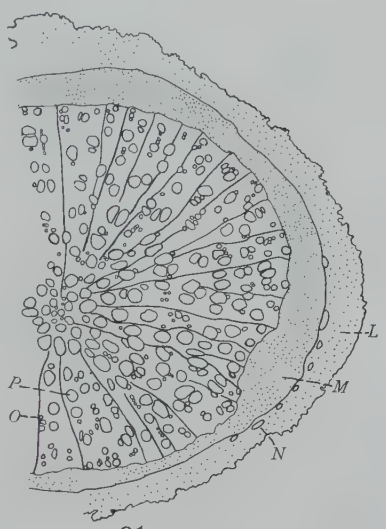

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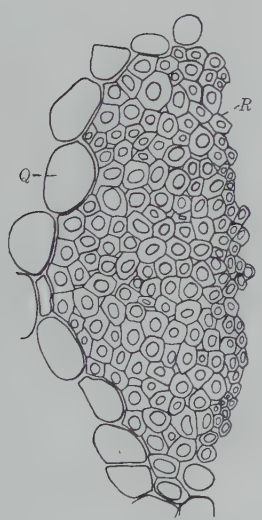

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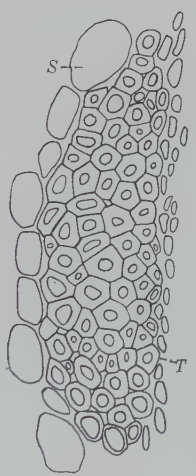

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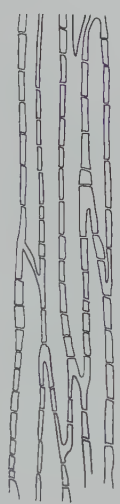

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PLATE XXIII.

PLATE XXIII. Showing method of supporting the growing seedlings.

PLATE XXIV.

PLATE XXIV. Wheat seedlings were grown for 18 days in extracts from soils in which the following kinds of organisms had grown. Reading from left to right: Ammonifier; B. radicicola; Azotobacter; B. prodigiosus; B. liquefaciens fluorescens; Cladothrix odorifera; Aspergillus niger; sterile soil; normal soil flora; B. Subtilis.

PLATE XXV.

Showing rate of development of various organisms in extracts of marsh soil cropped in different ways.

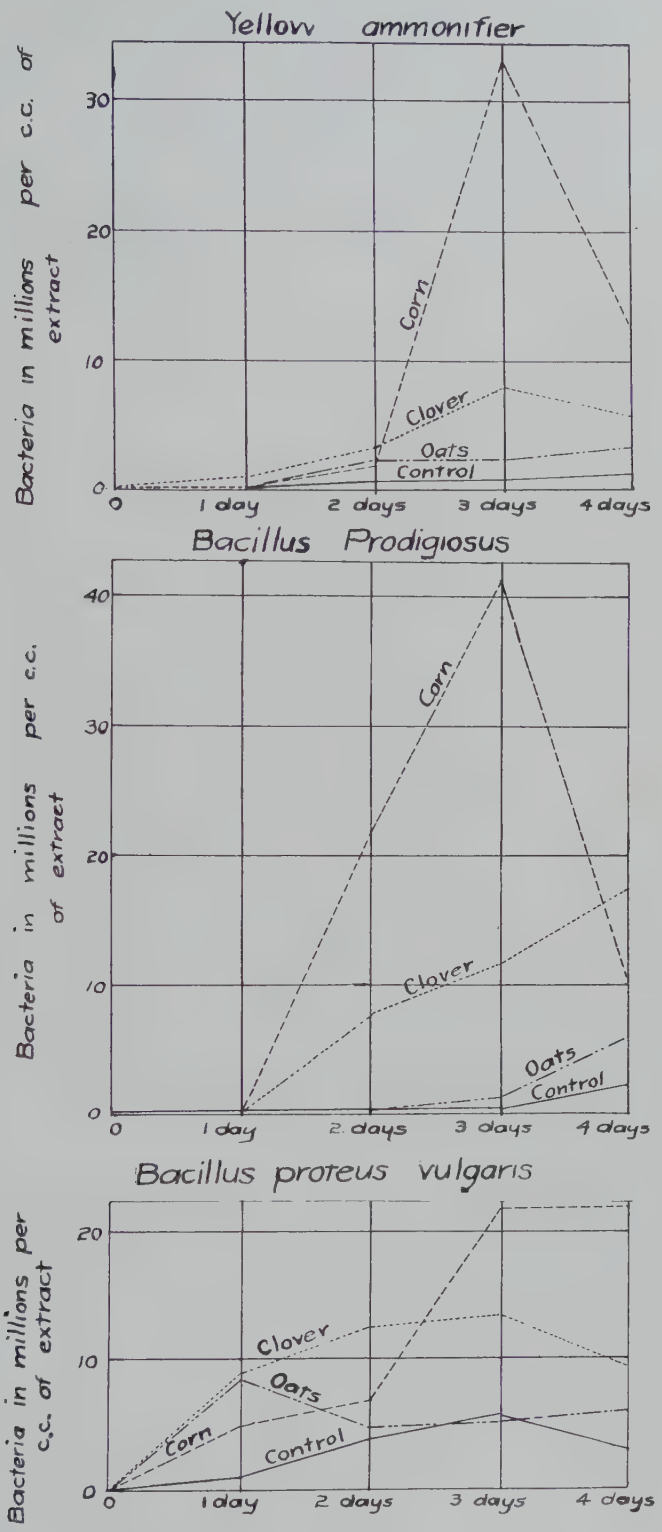
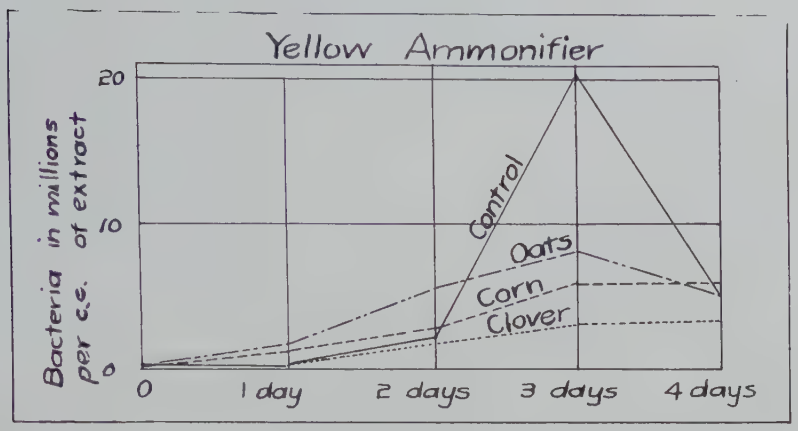
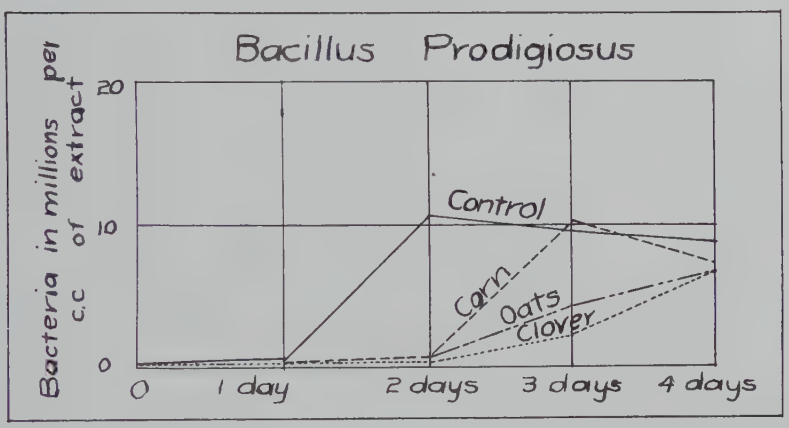


PLATE XXVI.

Showing rate of development of various organisms in extracts of loam soil cropped in different ways.





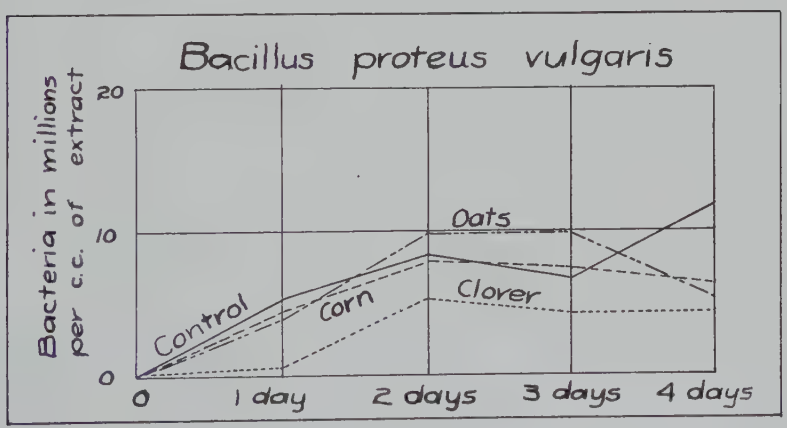


PLATE XXVII.

Showing rate of development of various organisms in extracts of sand soils cropped in different ways.

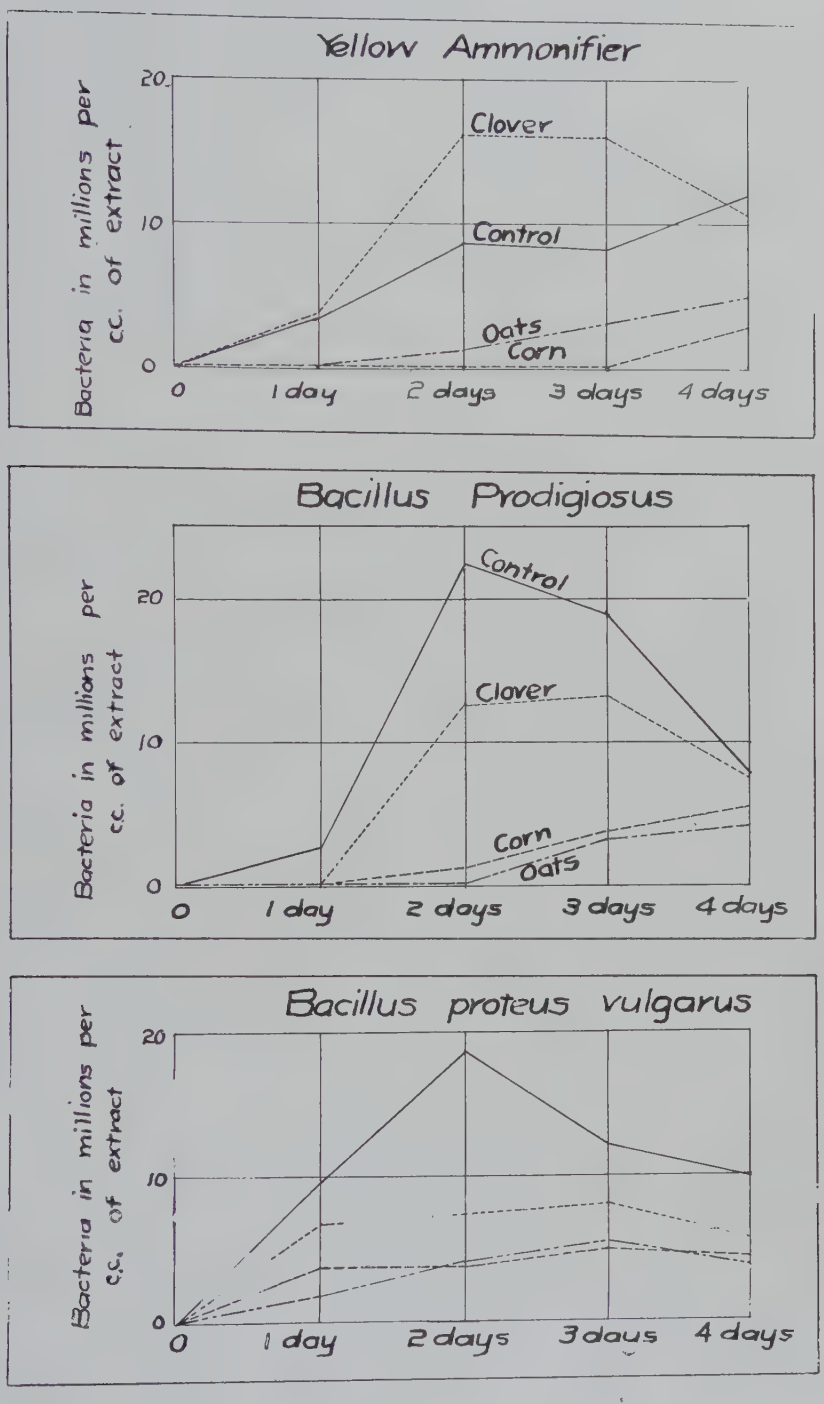


PLATE XXVIII.

FIG. 1.—*Side view of brain.* × 25.

A.—Olfactory lobes.
B.—Cerebral lobes.
C.—Optic thalami.
D.—Optic lobes.
E.—Cerebellum.
F.—Medulla.
G.—Spinal cord.
H.—Pineal body.
I.—Fossa rhomboidalis.
Par. Eye.—Parietal eye.
Inf.—Infundibulum.
Hyp.—Hypophysis.
Cil. Gang.—Ciliary ganglion.
Gass. Gang.—Gasserian ganglion.
Gen. Gang.—Geniculate ganglion.
1.—Olfactory nerve.
2.—Optic nerve.
3.—Ocular-motor nerve.
3c.—Connection with cilliary ganglion.
4.—Pathetic nerve.
5′, 5″, 5‴.—Trigeminal nerve with its three branches.
6.—Abduscent nerve.
7′, 7″, 7‴.—Facial nerve with its three branches.
8′, 8″.—Auditory nerve with its two branches.
9.—Glosso-pharyngial nerve.
10.—Vagus nerve.
11.—Spinal accessory nerve.
12.—Hypoglossary nerve.
13.—Spinal nerves.
An.—Anastomosis of the third and fifth nerves.

FIG. 2.—*Dorsal view of brain.* × 25.

All labels as in fig. 1.

FIG. 3.—*Posterior view of brain.* × 25.

All labels as in fig. 1.

PLATE XXVIII.

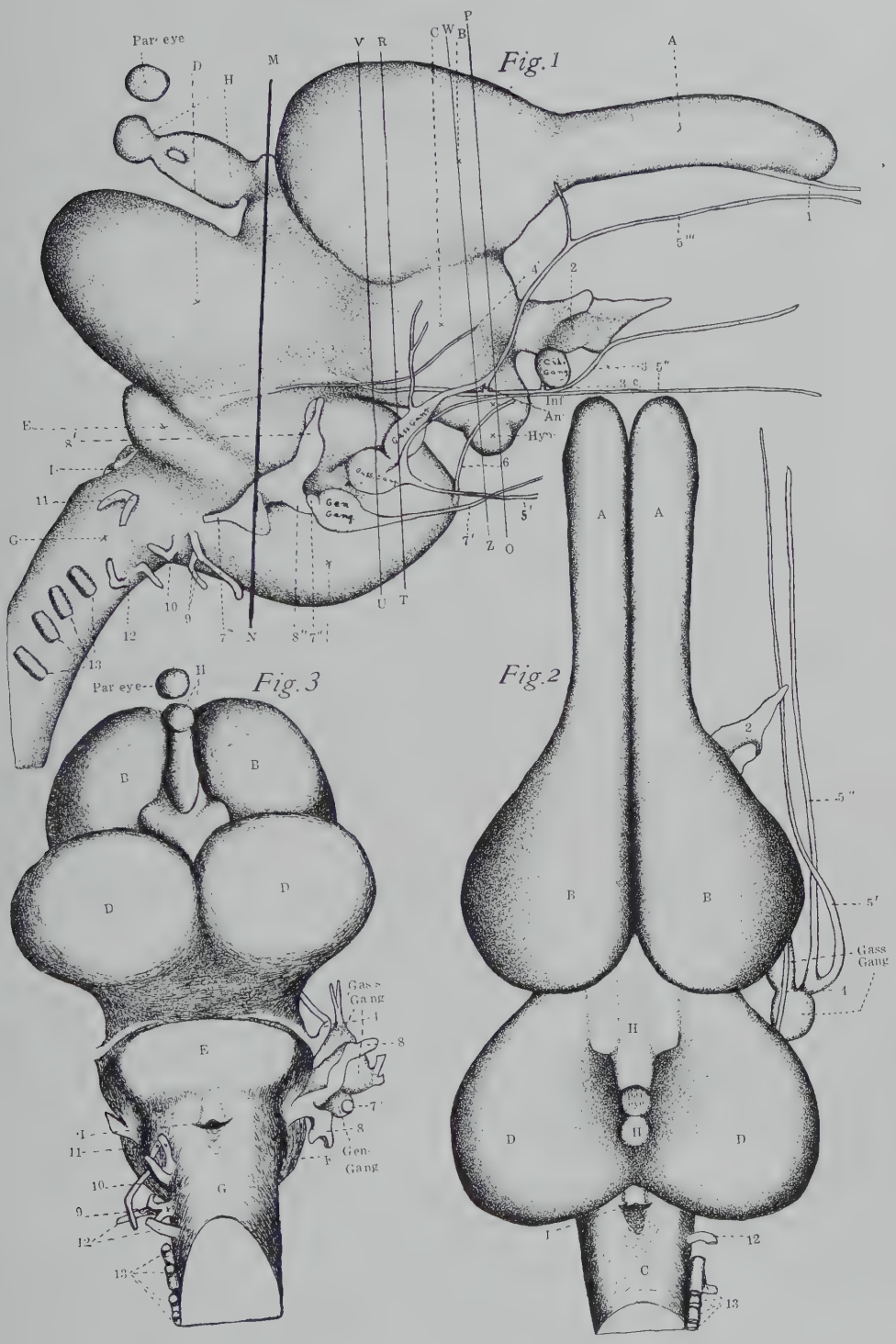


PLATE XXIX.

FIG. 4.—*Ventral view of brain.* × 26.

All labels as in fig. 1.

FIG. 5.—*Posterior view of model divided at MN.* × 26.

Aqu. Syl.—Aqueduct of Sylvius.
P.—Plexus.
Po.—Cavity of pineal body.
All other labels as in fig. 1.

FIG. 6.—*Anterior view of section PWZO.* × 26.

3V.—Third ventral of brain.
Ho.—Cavity of hypophysis.

PLATE XXIX.

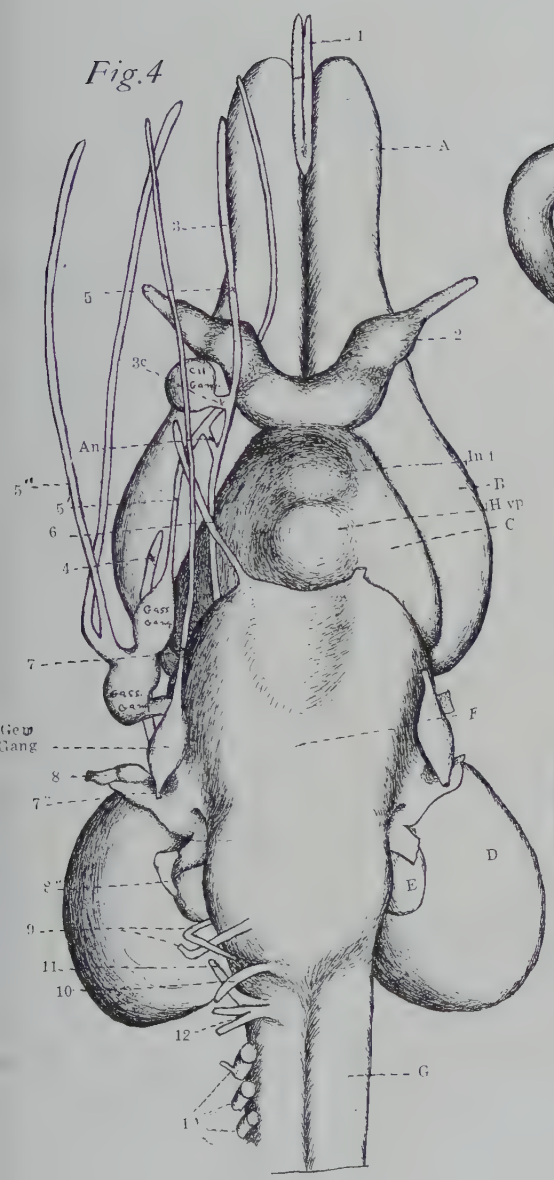


Fig. 4

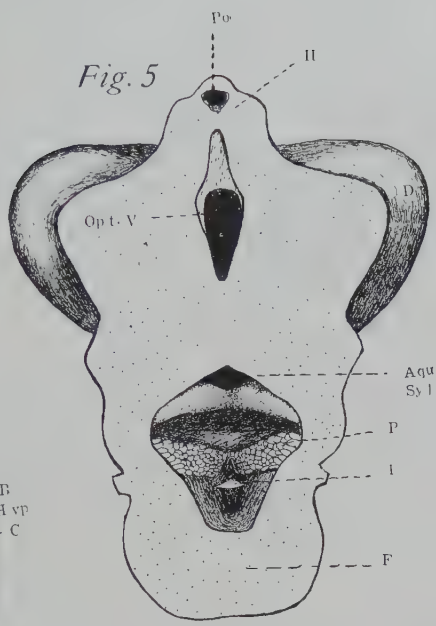


Fig. 5

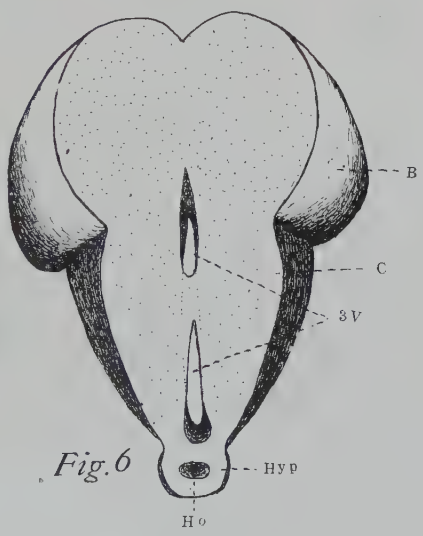


Fig. 6

PLATE XXX.

FIG. 7.—*Anterior view of section RVUT.* × 27.

3V.—Third ventricle of brain.
1V.—First ventricle of brain.
2V.—Second ventricle of brain.
For. Mon.—Foramen of Monro.
Pl.—Plexus.
All other labels as in fig. 1.

FIG. 8.—*Dorsal view illustrating brain cavities.* × 27.

Olf. V.—Olfactory ventricle.
1V.—First ventricle of brain.
2V.—Second ventricle of brain.
3V.—Third ventricle of brain.
Opt. V.—Optical ventricles.
For. Mon.—Foramen of Monro.
Sp. Cnl.—Spinal canal.

FIG. 9.—*Side view illustrating brain cavities.* × 27.

4V.—Fourth ventricle of brain.
Pl—Plexus.
Ho.—Cavity of hypophysis.
Aqu. Syl.—Aqueduct of Sylvius.
Other labels as in fig. 8.

FIG. 10.—*Diagram of cavities of pineal body and parietal eye in vertical plane.* × 54.

FIG. 11.—*Diagram of cavities of pineal body and parietal eye in horizontal plane.* × 67.

PLATE XXX.

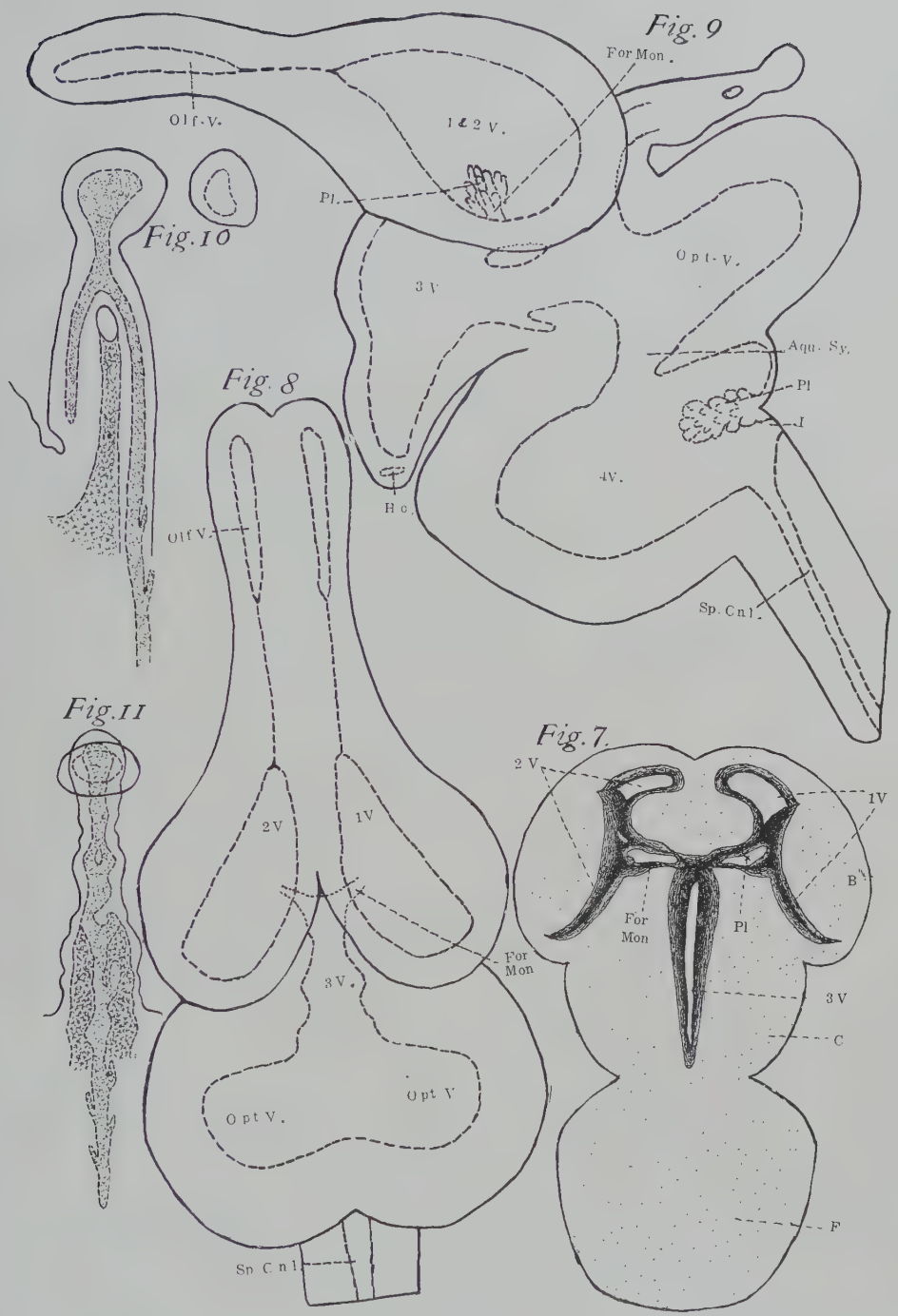


Fig. 9
For Mon.
Olf. V.
1 & 2 V.
Pl.
Opt. V.
3 V
Aqu. Sy.
Pl
I
4V.
Sp. Cnl.
Fig. 10
Fig. 8
Olf V.
Hc.
Fig. 11
2V
1V
For Mon
3V.
Opt V.
Opt V
Sp Cnl
Fig. 7.
2 V
1V
B
For Mon
Pl
3 V
C
F

PLATE XXXI.

Explanation as in fig. 10

FIG. 12.—*Drawing of series of sections through optic chiasma.*

FIG. 13.—*Diagram to illustrate mode of crossing of nerves.*

FIG. 14.—*Outline drawing of adult brain.*

FIG. 15.—*Outline drawing of embryonic brain.*

PLATE XXXI.

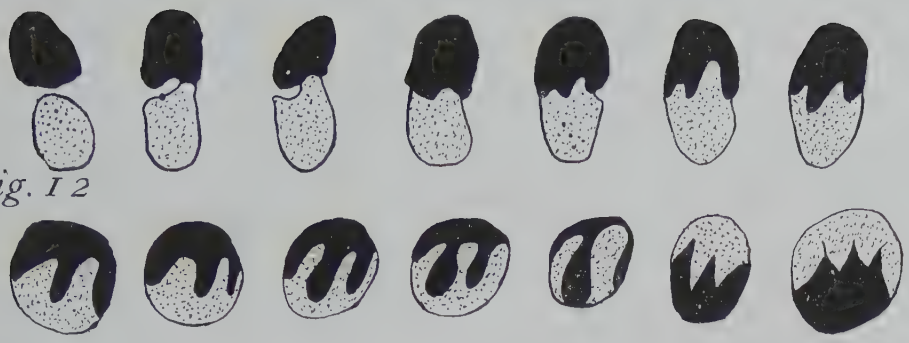


Fig. 12

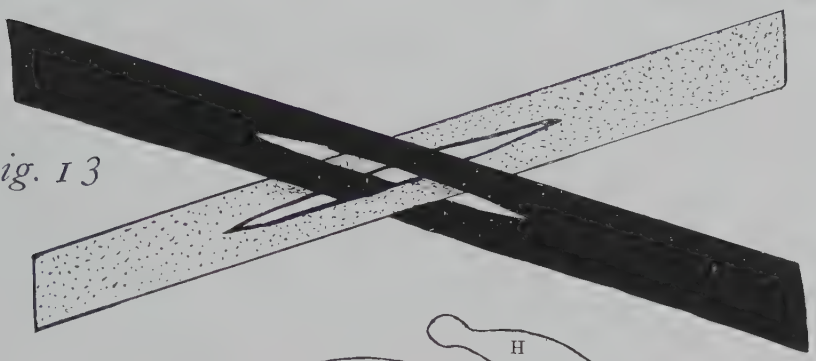


Fig. 13

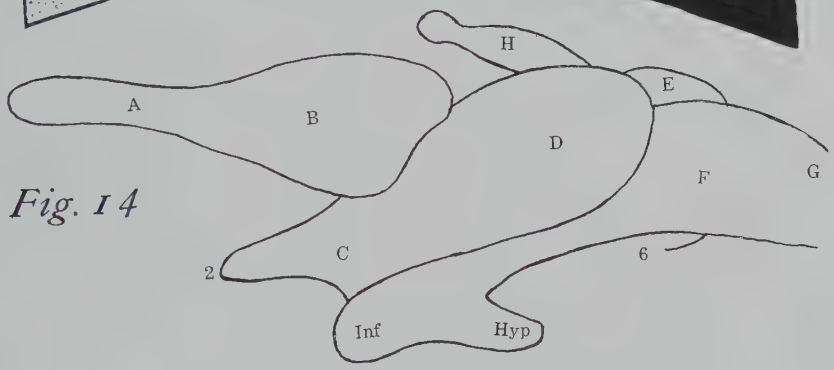


Fig. 14

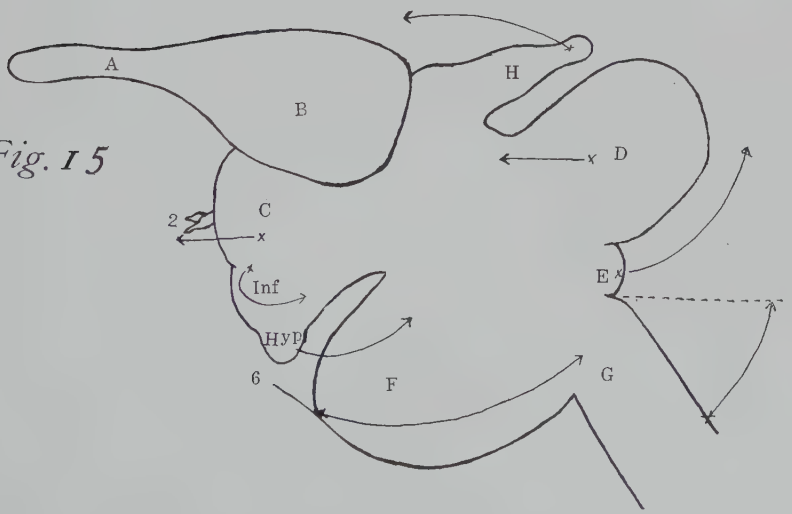


Fig. 15

PLATE XXXII.

1. Neuroplasm. Metaphase gives an idea of the size and shape of chromosomes.
2. Ectoblast. Anaphase showing loop form as they come to the poles.
3. Ectoblast. Splitting.
4. Ectoblast. Metaphase.
5. Pigment showing full number of chromosomes and the difficulty in measuring.
6. Gryllus domesticus. First spermatocyte.
7. Muscle. Metaphase.

PLATE XXXII.

Fig. 1

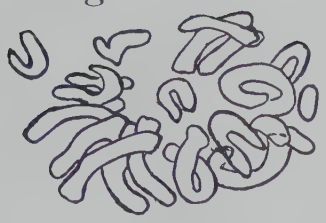


Fig. 2

Fig. 3

Fig. 4

Fig 6

Fig 7

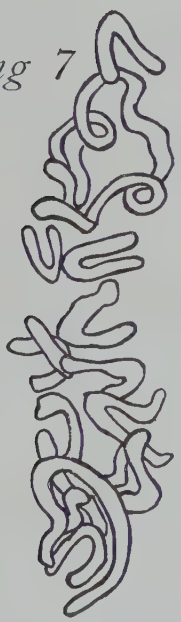


Fig 5

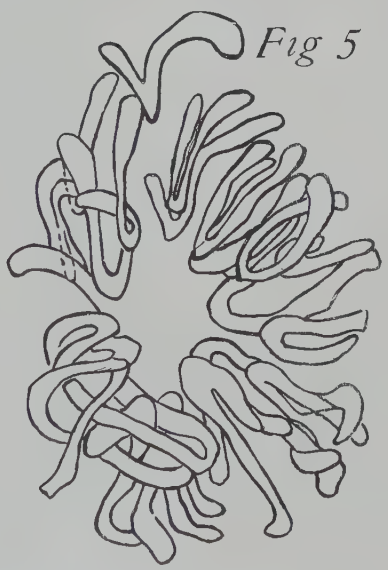


PLATE XXXIII.

Figures magnified 485 diameters.

page

FIG. 1. *Enchelydon farctus* C. & L. 152
FIG. 2. *Prorodon edentatus* C. & L. 153
FIG. 3. *Prorodon teres* Ehr. 152
FIG. 4. *Prorodon Lieberkuhnii* Bronn. 153
FIG. 5. *Coleps hirtus* Ehr. An individual that has just divided, showing absence of armature on the anterior half. 153

PLATE XXXIII.

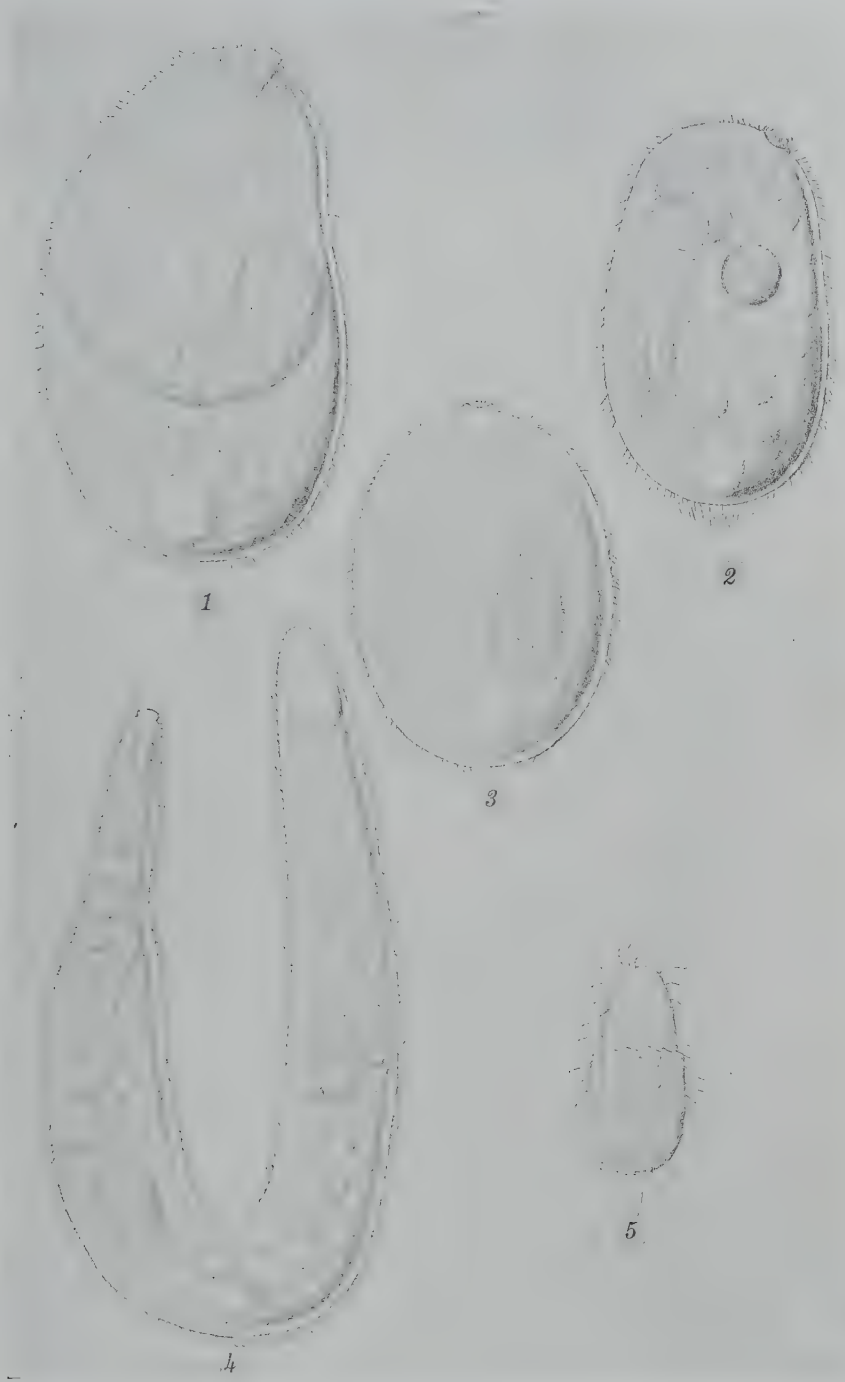


PLATE XXXIV.

Figures magnified 485 diameters.

		page
Fig. 6.	*Lacrymaria olor* O. F. Mull	153
Fig. 7.	*Trachelius ovum* Ehr	155
Fig. 8.	*Lacrymaria olor*, contracted	153
Fig. 9.	*Coleps hirtus* Ehr	152
Fig. 10.	*Lacrymaria truncata* Stokes	153

PLATE XXXIV.

PLATE XXXV.

Figures magnified 485 diameters.

		page
Fig. 11.	*Dileptus gigas* C. & L.	154
Fig. 12.	*Loxodes rostrum* O. F. Mull	155
Fig. 13.	*Chilodon cucullus* Mull	156
Fig. 14.	*Lionotus Urzesniowskii* S.K	154
Fig. 15.	*Lionotus fasciola* Ehr	154
Fig. 16.	*Chilodon megalotrocha* Stokes	157

PLATE XXXV.

PLATE XXXVI.

Figures magnified 485 diameters.

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FIG. 17. *Nassula aurea* Ehr 156
FIG. 18. *Nassula rubens* C. & L. 156
FIG. 19. *Nassula rubens* encysted. 156

PLATE XXXVI.

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PLATE XXXVII.

Figures magnified 485 diameters.

		page
Fig. 20.	*Colpoda cucullus* Ehr	158
Fig. 21.	*Colpoda helia* Stokes	158
Fig. 22.	*Frontonia leucas* Ehr	157
Fig. 23.	*Colpidium putrinum* Stokes	158
Fig. 24.	*Colpidium striatum* Stokes	158

PLATE XXXVII.

PLATE XXXVIII.

Figures magnified 485 diameters.

page

FIG. 25. *Paramæcium caudatum* Ehr. 159
FIG. 26. *Tillina magna* Gruber 159
FIG. 27. *Cyclidium glaucoma* Ehr 160
FIG. 28. *Paramæcium bursaria* Ehr. 159

PLATE XXXVIII.

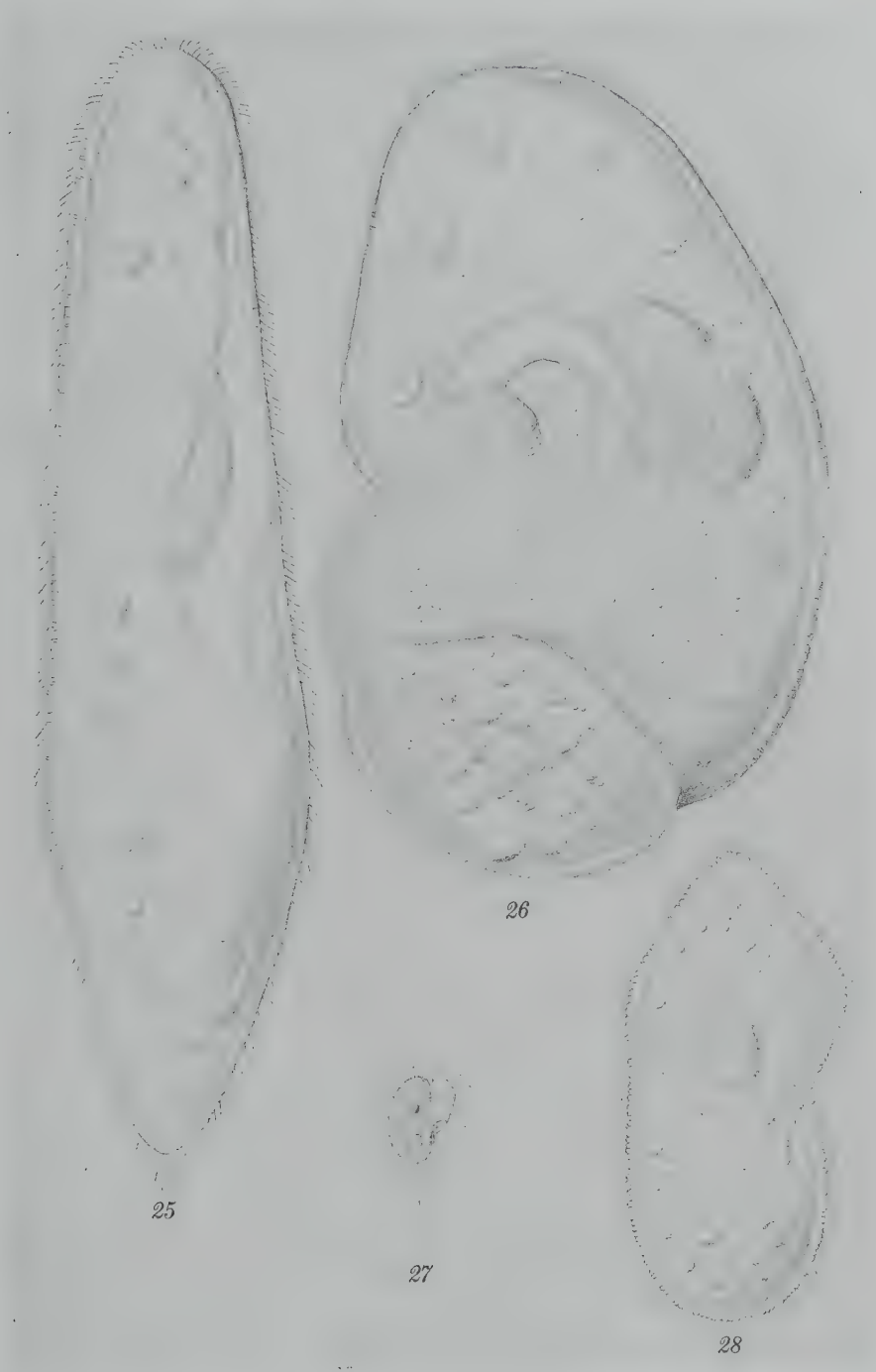

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PLATE XXXIX.

Figures magnified 485 diameters.

page

FIG. 29. *Metopus sigmoides* Mull 161
FIG. 30. *Condylostoma stagnale* Wrz 162
FIG. 31. *Metopides acuminata* Stokes 161
FIG. 32. *Nyctotherus cordiformis* Stein 160

PLATE XXXIX.

PLATE XL.

Figures 33-35 magnified 200 diameters; figure 36 magnified 485 diameters.

page

FIG. 33. *Spirostomum teres* C. & L. 162
FIG. 34. *Stentor roeselii* Ehr 163
FIG. 35. *Spirostomum ambiguum* Ehr 161
FIG. 36. *Halteria grandinella* Mull 163

PLATE XL.

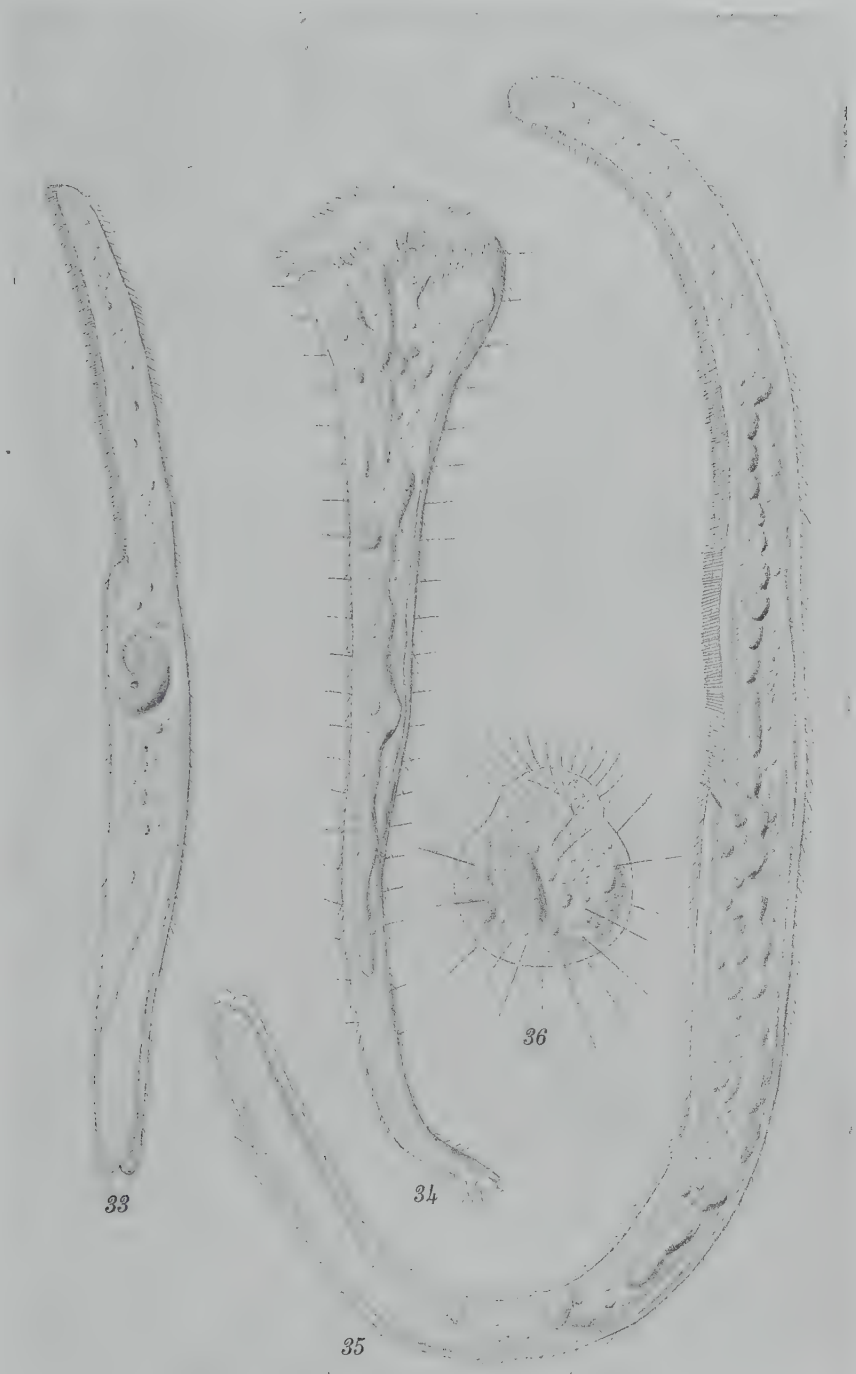

PLATE XLI.

Figure 37 magnified 200 diameters.

page

FIG. 37. *Stentor caeruleus* Ehr. 163

FIG. 38. *Stentor cæruleus.* Low-power drawing of completely expanded animal 163

PLATE XLI.

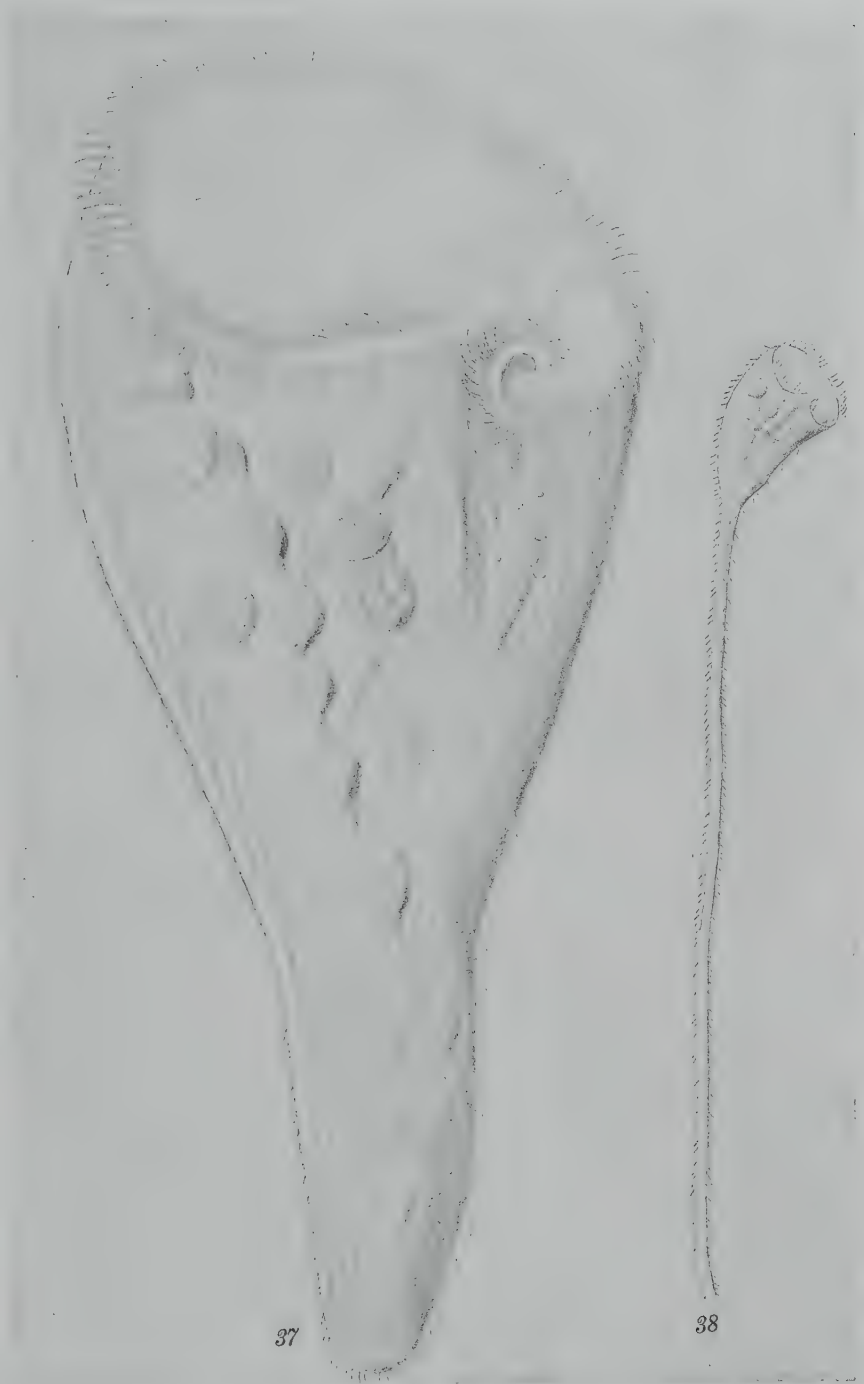

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PLATE XLII.

Figures magnified 485 diameters.

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FIG. 39. *Onychodromus grandis* Stein 165
FIG. 40. *Urpleptus agilis* Eng 164
FIG. 41. *Gastrostyla Steinii* Eng 165

PLATE XLII.

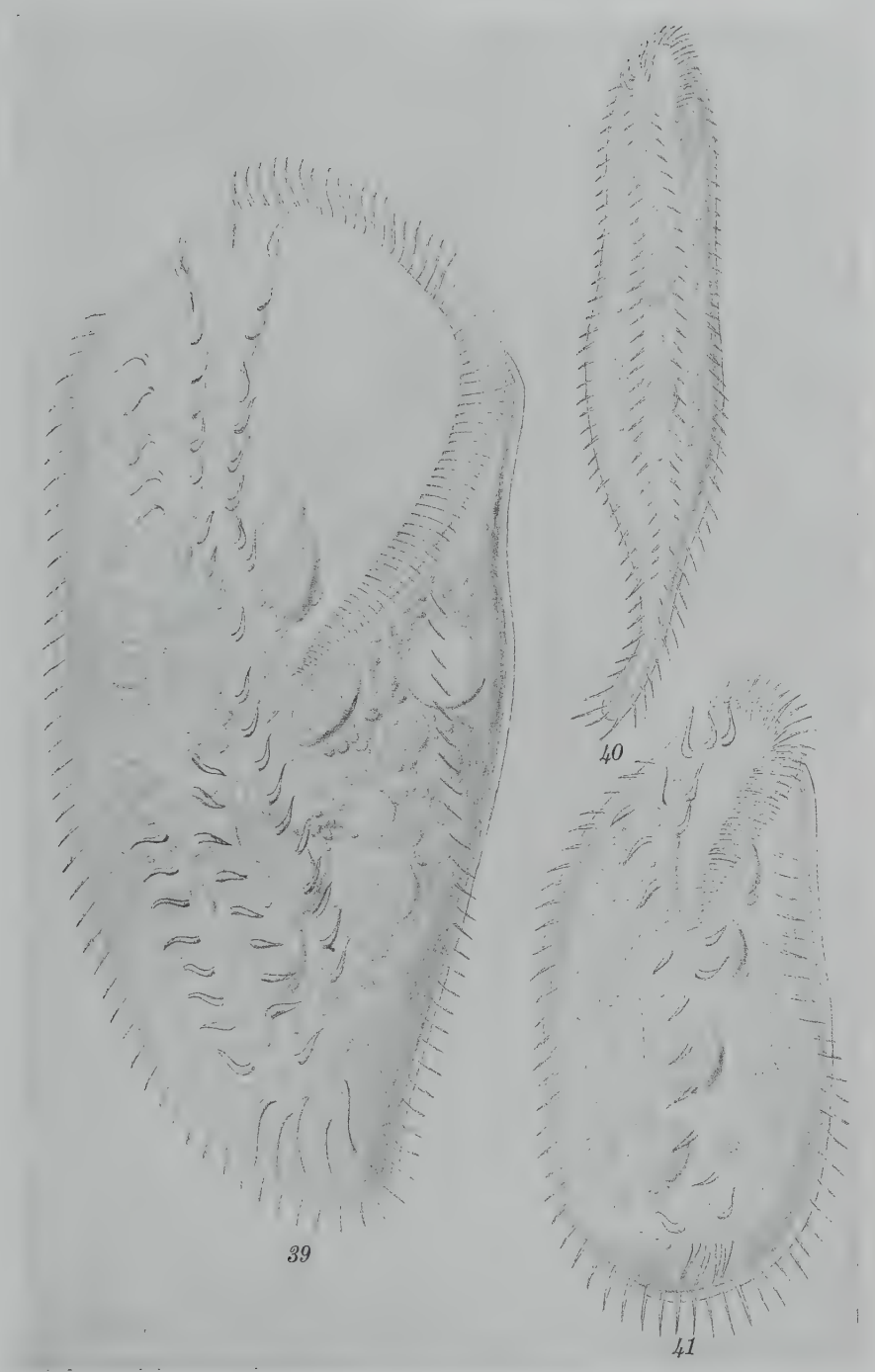

PLATE XLIII.

Figures magnified 485 diameters.

page

FIG. 42. *Stylonychia pustulata* Ehr 166
FIG. 43. *Stylonychia mytilus* Ehr 166
FIG. 44. *Stylonychia notophora* Stokes 166
FIG. 45. *Oxytricha bifaria* Stokes 165
FIG. 46. *Oxytricha pellionella* Mull 166

PLATE XLIII.

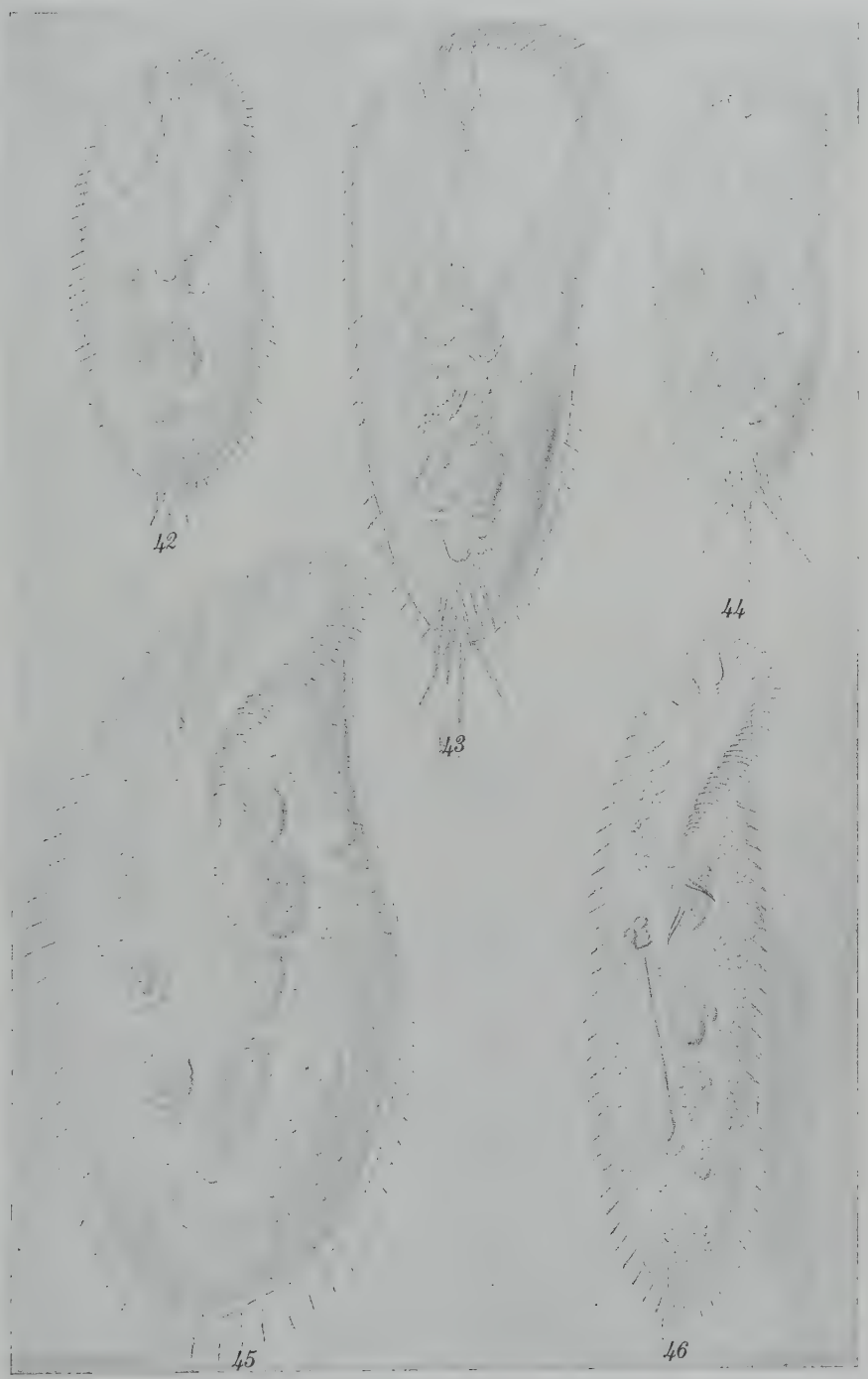

PLATE XLIV.

Figures magnified 485 diameters.

page

FIG. 47. *Euplotes patella* Ehr 167
FIG. 48. *Urostyla grandis* Ehr 167
FIG. 49. *Euplotes carinata* Stokes 167
FIG. 50. *Aspidisca costata* Duj 167

PLATE XLIV.

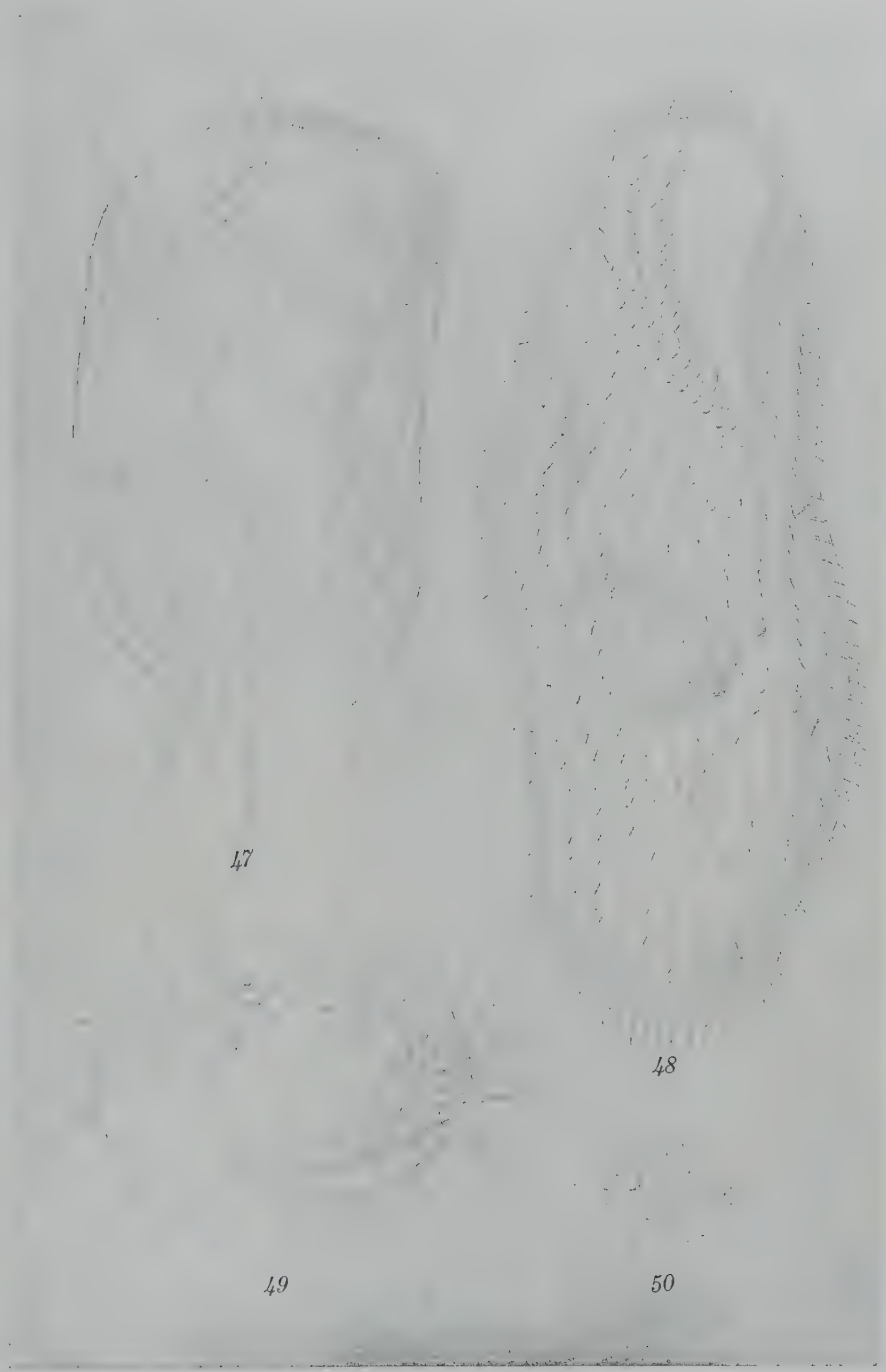

PLATE XLV.

Figures magnified 485 diameters.

page

FIG. 51. *Vorticella cucullus* From. . . . 170
FIG. 52. *Vorticella longifilum* S. K. . . . 170
FIG. 53. *Vorticella gracilis* Duj. . . . 169
FIG. 54. *Vorticella microstoma* Ehr. . . . 170
FIG. 55. *Vorticella convallaria* Linn. . . . 171
FIG. 56. *Vorticella aquae-dulcis* Stokes. . . . 171
FIG. 57. *Vorticella simulis* Stokes. . . . 171
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PLATE XLV.

PLATE XLVI.

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PLATE XLVI.

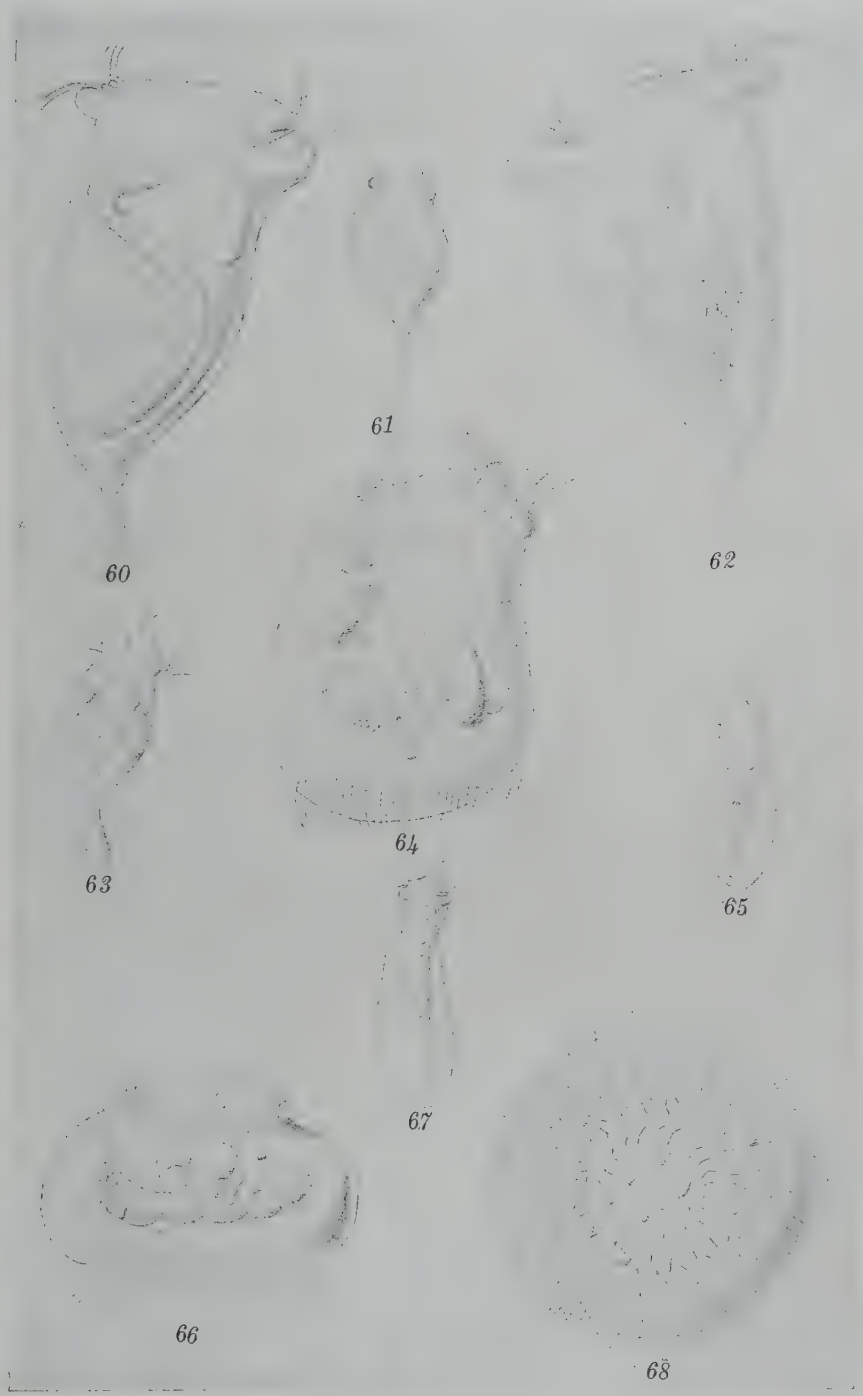

PLATE XLVII.

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PLATE XLVII.

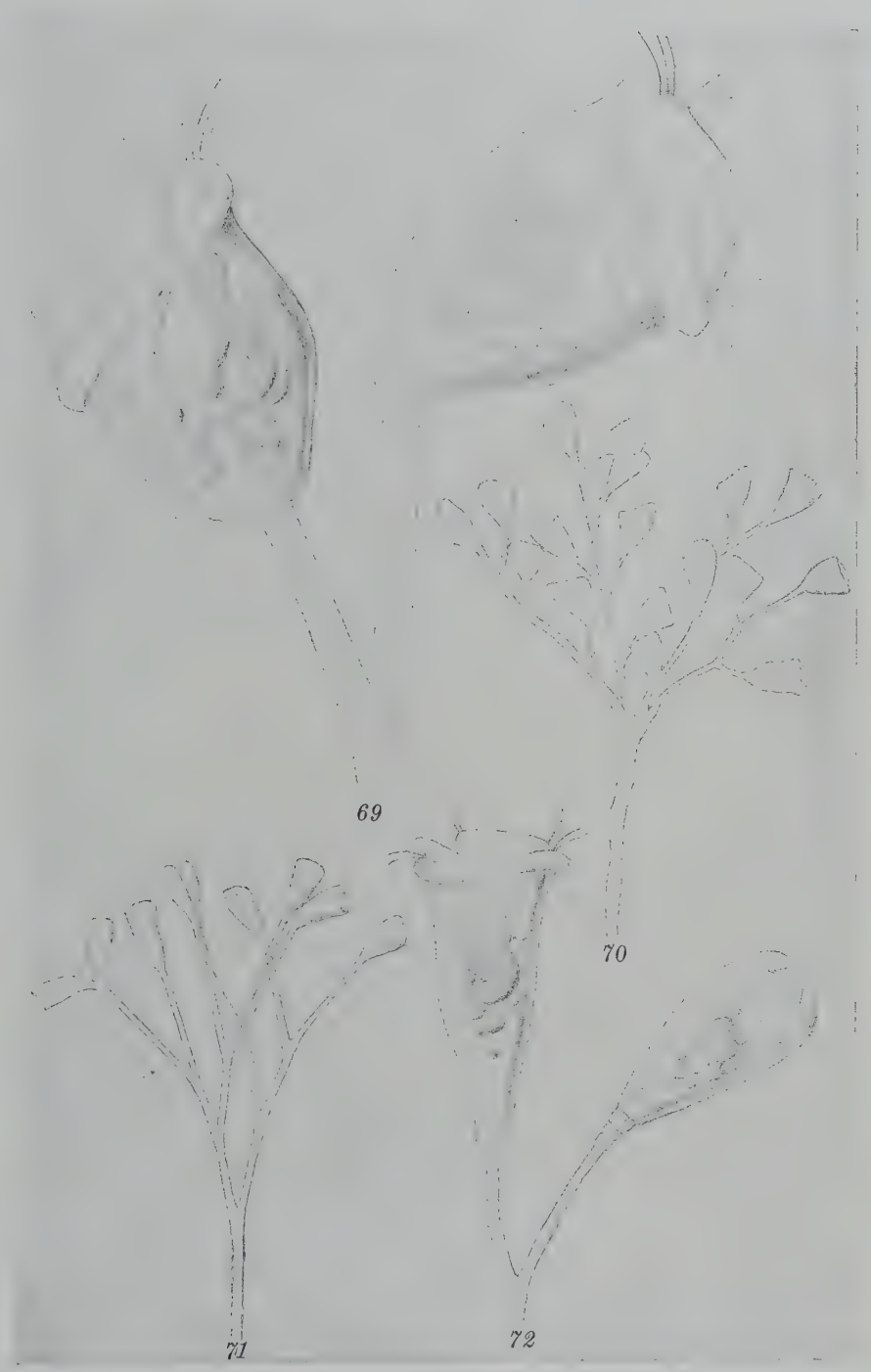

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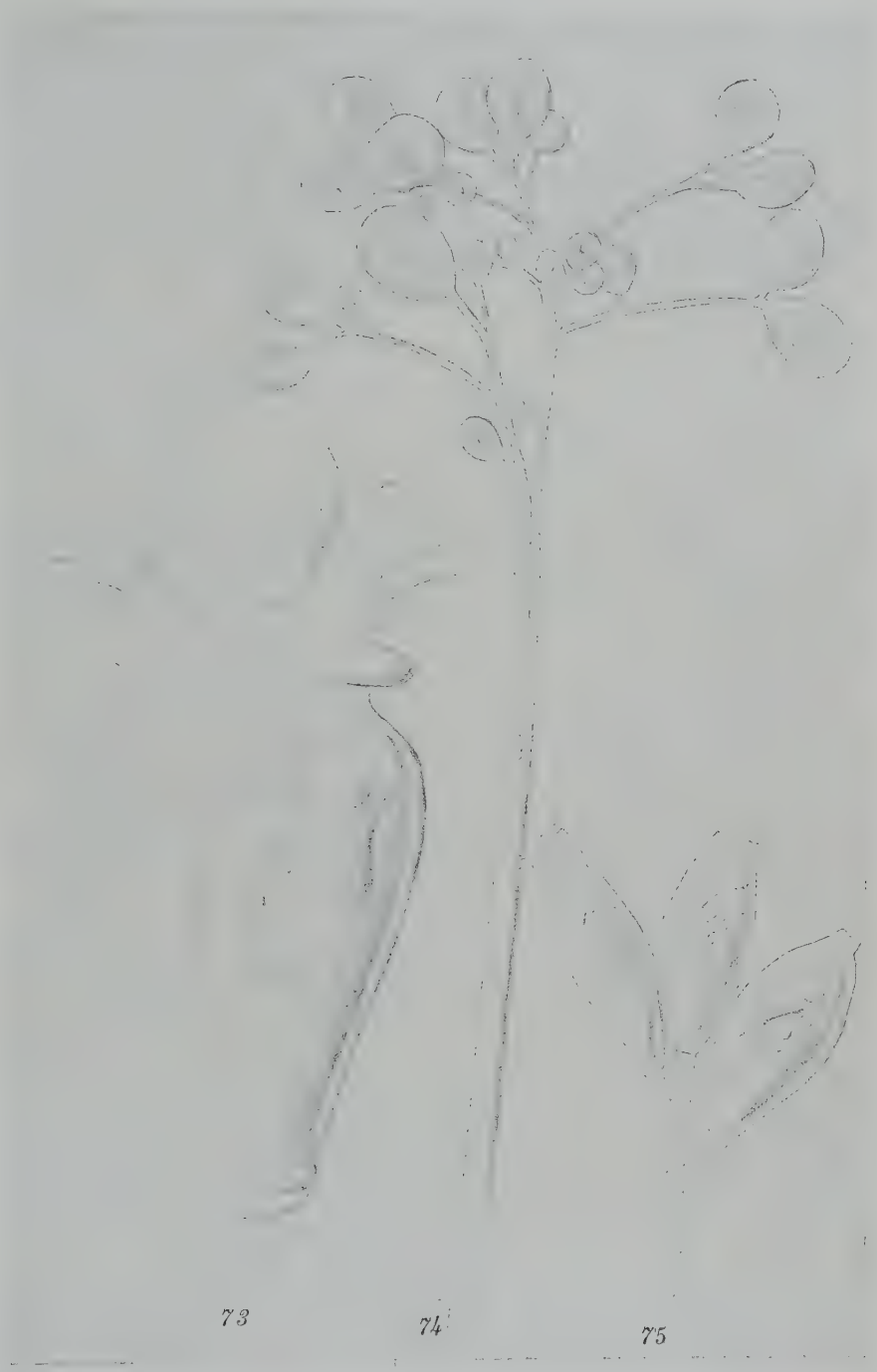
PLATE XLVIII.



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Figures magnified 485 diameters.

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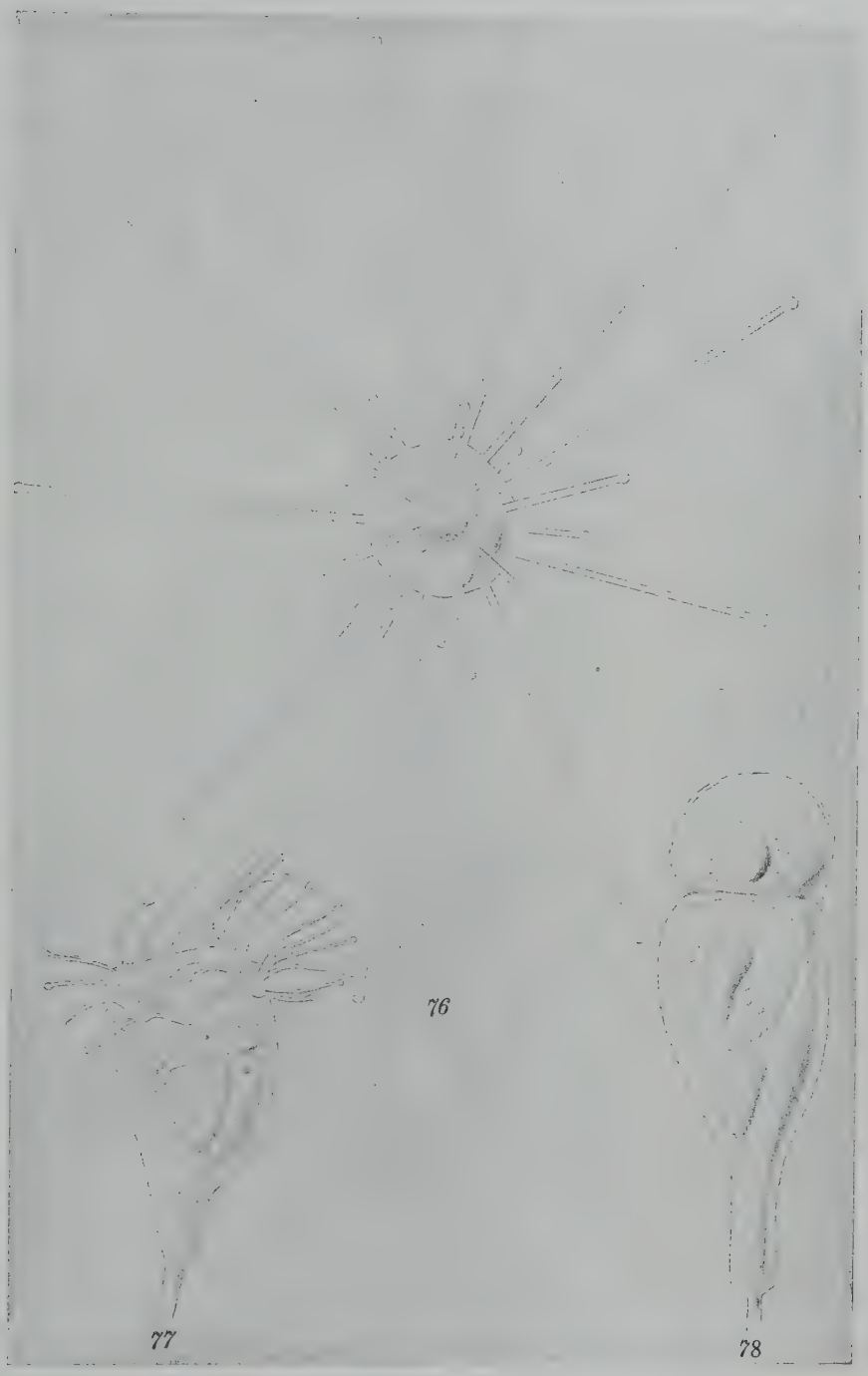


PLATE L.

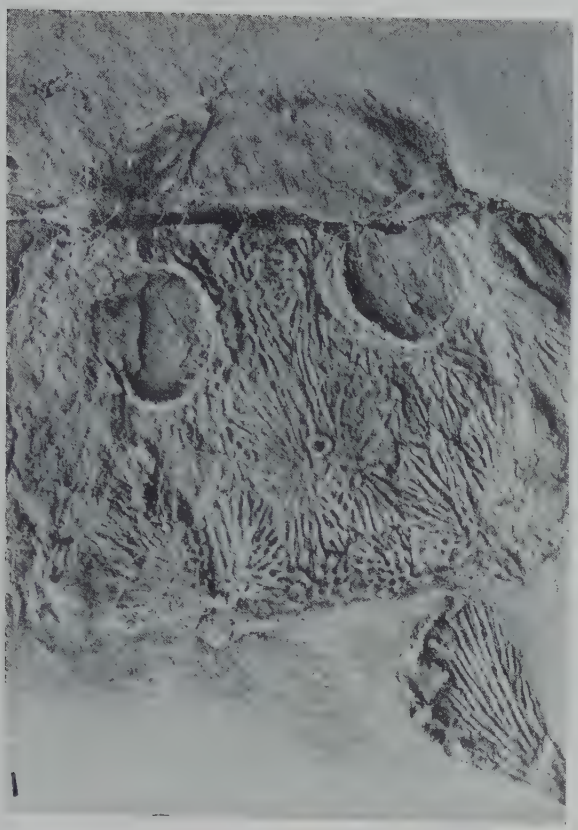
FIGURE 1. Skull of *Erpetosaurus tabulatus* Cope, showing a perfect application of the method of using the ammonium chloride deposit. The effect had been heightened by the application of a white wash to the background of matrix. It will be clearly seen that all of the details of the skull structure are evident. This method is especially useful in studying the course of the lateral line canals on the small amphibian skulls. The supraorbital canals are thus indicated as shadows above the orbits and were not previously observed.

FIGURE 2. Skull of *Erpetosaurus lævis* Moodie, showing the adaptability of the method to irregular surfaces. The membranous skull bones had become loosened from this cast and left only their impressions. The block of coal is much broken, yet there are many details which are evident on close study.

FIGURE 3. An example of an imperfect fossil, representing a form identified by Cope as *Molgophis wheatleyi* and showing an improper use of the ammonium chloride deposit. The upper part of the fossil is not covered uniformly with the rest, and will illustrate the advantage of the ammonium chloride deposit as an illuminant for dark surfaces.

FIGURE 4. The fossil is a portion of the skeleton of *Ptyonius nummifer* Cope, and illustrates the disadvantages of the deposition of too much ammonium chloride on the specimen. On removing the deposit by breathing on it and making another more tenuous deposit the fossil was clearly evident.

PLATE L.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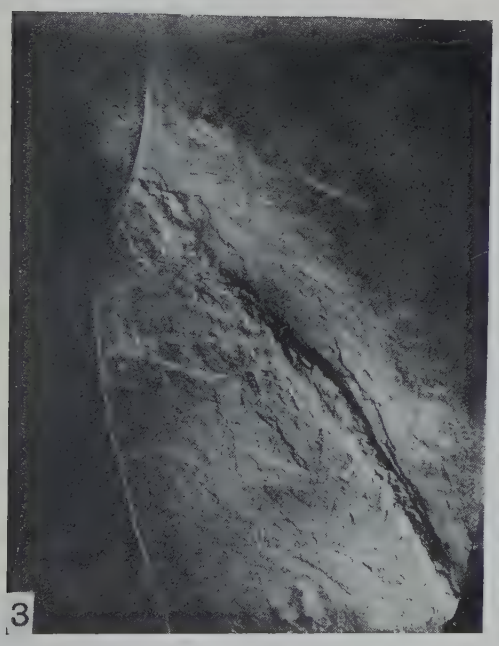
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PLATE LI.

FIG. 1.—Longitudinal section through the ectoderm, entoderm and mesoglea of the peduncle at the base of a bud, showing the germ cells in the ectoderm migrating toward the bud.

FIG. 2.—Transverse section through the peduncle in the region of a developing bud, showing germ cells in the entoderm. Stage A.

FIG. 3.—Median longitudinal section through a medusa bud, showing germ cells in the entoderm and the thickening of the ectoderm at the apex. Stage B.

ABBREVIATIONS FOR ALL FIGURES.

B. Ent., Bud entoderm.
Cav. Man., Cavity of the manubrium.
Cav. Med., Cavity of the medusa.
E., Egg.
Ect., Ectoderm.
Ect. Th., Ectodermal thickening.
Ent., Entoderm.
Ent. Man., Entoderm of the manubrium.
Ent. Umb., Entoderm of the umbrella.
Ext. Ect. Umb., External ectodermal layer of the umbrella.
Ext. Glk., External layer of the "glockenkern."
Int. Ect. Umb., Internal ectodermal layer of the umbrella.
Int. Glk., Internal layer of the "glockenkern."
G. C., Germ cell.
Mes., Mesoglea.
Nt., Nematocyst cell.
R. C., Radial canal.
S. C., Somatic cell.
Spm., Sperm.

PLATE LI.

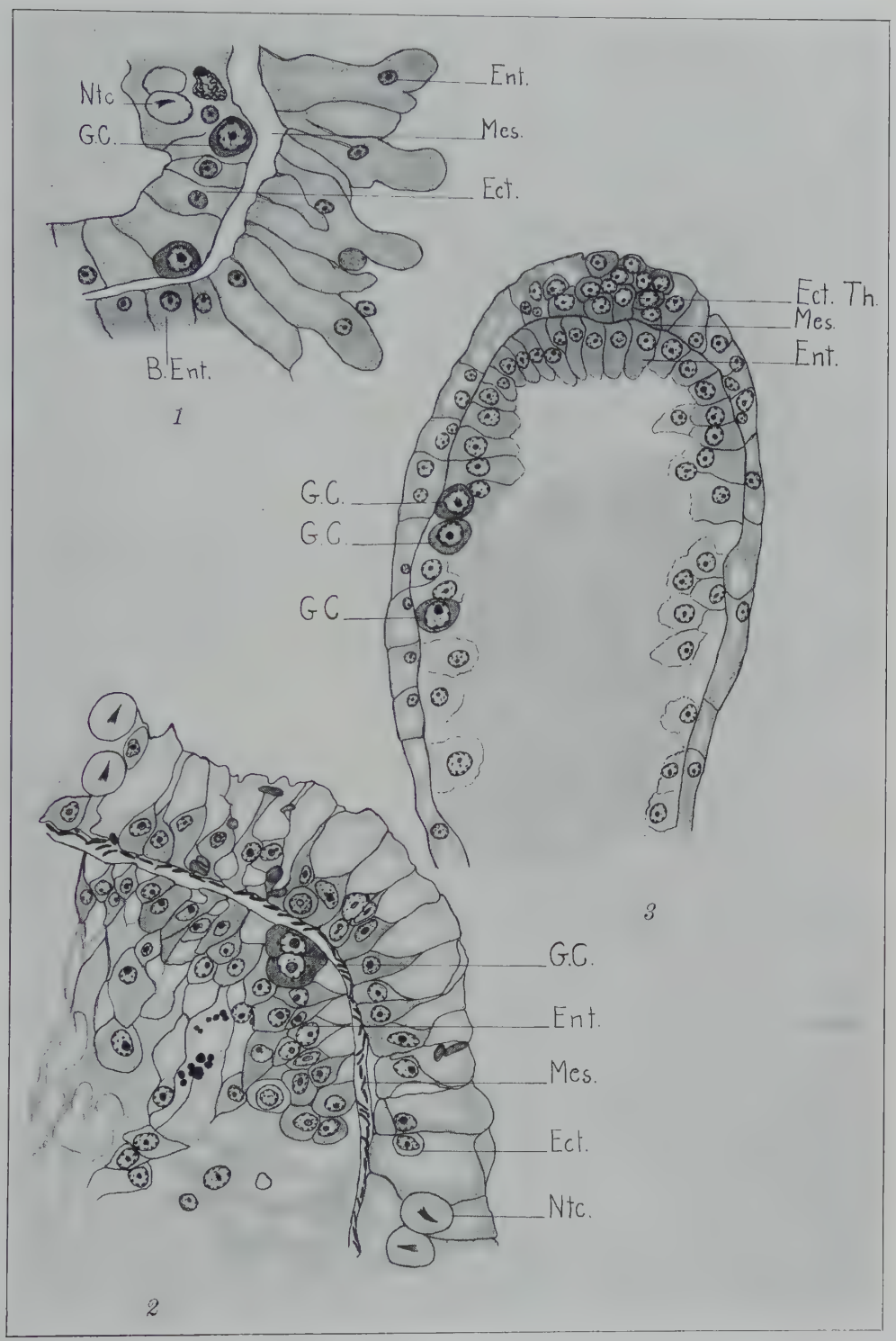

Ntc.
G.C.
Ent.
Mes.
Ect.
B. Ent.
1
Ect. Th.
Mes.
Ent.
G.C.
G.C.
G.C.
3
G.C.
Ent.
Mes.
Ect.
Ntc.
2

PLATE LII.

FIG. 4.—Median longitudinal section through a bud, showing the formation of the "glockenkern" at the apex. Stage C.

FIG. 5.—Median longitudinal section through a bud, showing germ cells migrating into the pear-shaped "glockenkern." Stage D.

FIG. 6.—Median longitudinal section through a bud, showing the separation of the two layers of the "glockenkern" cell mass and the formation of the manubrium. Stage E.

PLATE LII.

Ect.
Glk.
Ent.
G.C.
4
Ect
Ent
Glk.
G.C
G.C
5
G.C.
Man
Cav Man.
Ect.
Ext Glk.
Int. Glk.
G.C.
G.C
6

PLATE LIII.

FIG. 7.—Semidiagrammatic median longitudinal section through a bud, showing complete differentiation of all the cell layers.

FIG. 8.—Semidiagrammatic transverse section through a medusa at the same stage of development as the one shown in figure 7, showing the cell layers and the radial canals.

FIG. 9.—Semidiagrammatic median longitudinal section through a medusa, showing the manubrium breaking through the outer capsule.

FIG. 10.—Segment of a transverse section through the manubrium of an older female medusa.

FIG. 11.—Segment of a transverse section through the manubrium of a male medusa, with a diameter equal to that of the medusa shown in figure 10.

PLATE LIII.

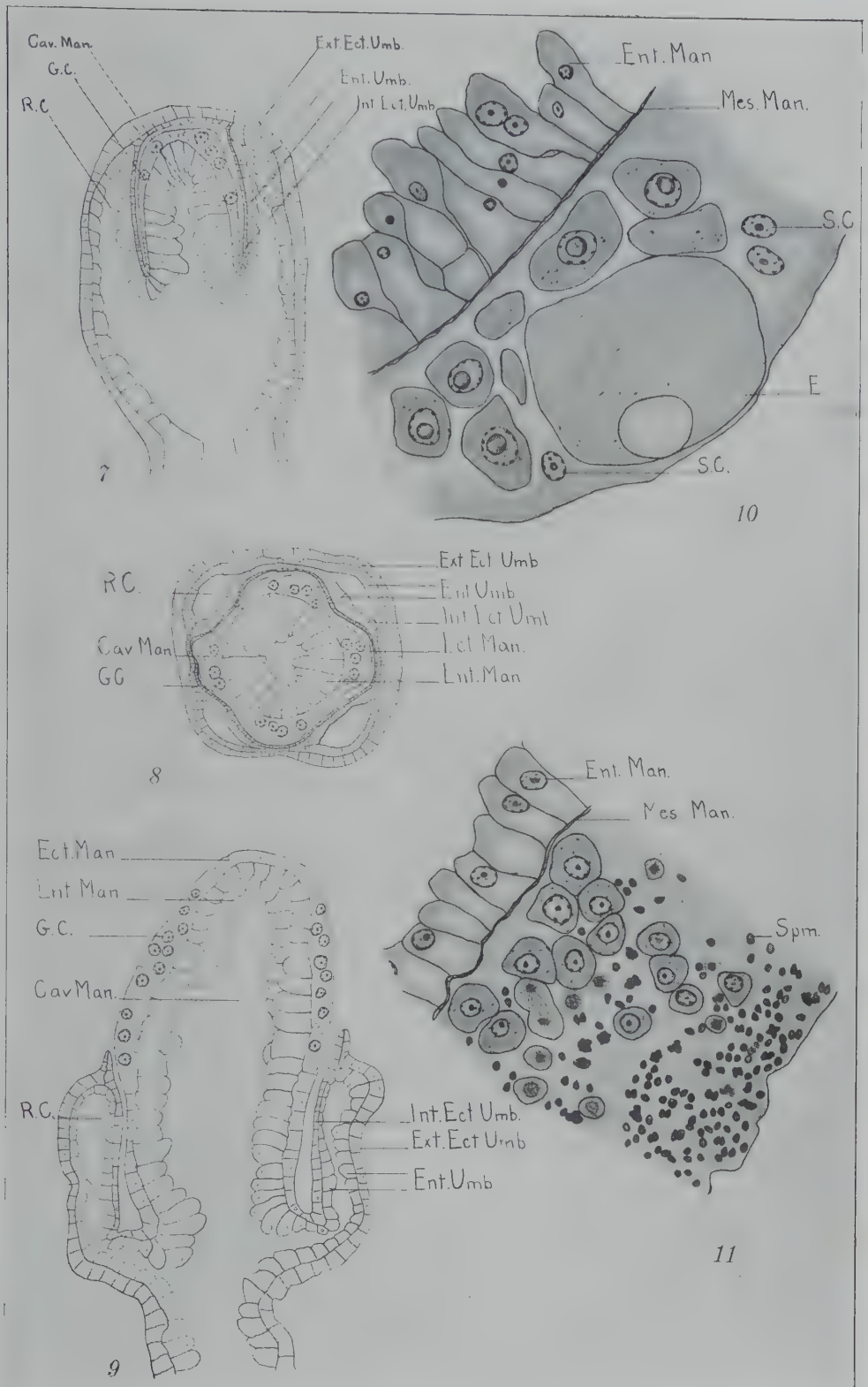

Cav. Man.
G.C.
R.C.
Ext. Ect. Umb.
Ent. Umb.
Int Ect. Umb.
7
Ent. Man
Mes. Man.
S.C.
E
S.C.
10
R.C.
Cav Man
GG
Ext Ect Umb
Ent Umb
Int Ect Umb
Ect Man.
Ent Man
8
Ect. Man
Ent Man
G.C.
Cav Man.
R.C.
Int. Ect Umb.
Ext. Ect Umb
Ent. Umb
9
Ent. Man.
Mes Man.
Spm.
11

PLATE LIV.

FIG. 1. Tip of leaf showing venation, × 66: *a*, group of tracheids where veins end; *b*, free endings of veinlets.

FIG. 2. Venation farther back from the apex, × 66.

FIG. 3. Detailed drawing of group of tracheids at end of vein, × 275.

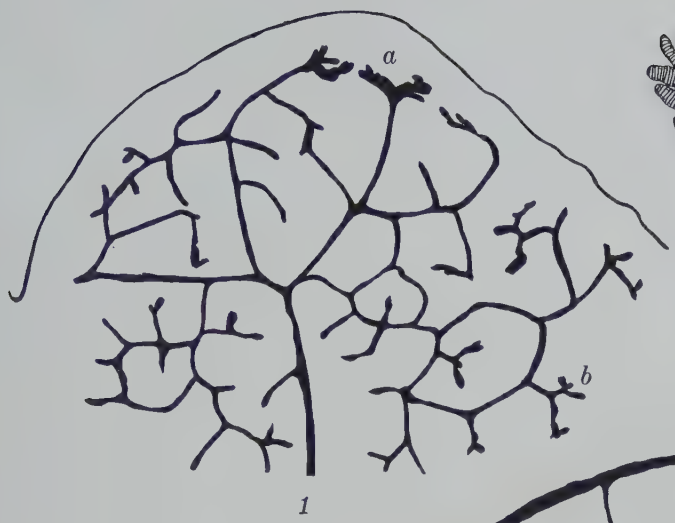
FIG. 4. Stellate hair from epidermis of leaf, × 175.

FIG. 5. Cross section of stoma of leaf, × 375: *a*, air chamber.

FIG. 6. Cross section lateral view of stoma.

FIG. 7. Epidermis of stem showing stomata, × 275.

PLATE LIV.



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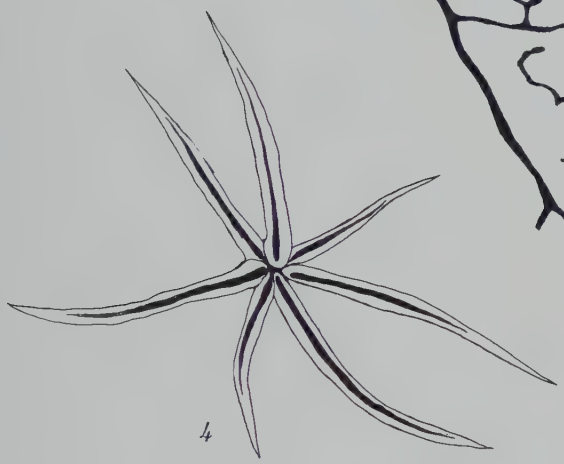

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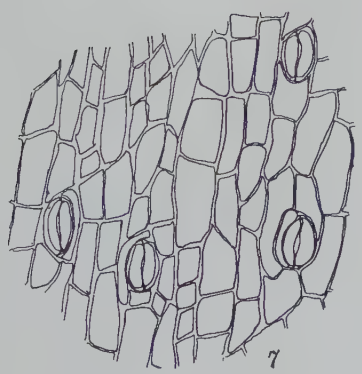


7

PLATE LV.

FIG. 8. Cross section of leaf showing part of a large vein, × 375: *a*, epidermal cells; *b*, mucilagenous cell; *c*, palisade cell; *d*, chloroplasts; *e*, tracheids; *f*, glandular hair; *g*, long border parenchyma cells surrounding the veins.

FIG. 9. Cross section of a large vein, × 375: *a*, vascular bundle; *b*, border parenchyma cell; *c*, mucilagenous modification of cell walls.

FIG. 10. Cross section of leaf, × 275; *a*, palisade cells; *b*, small vein; *c*, stoma in cross section; *d*, longitudinal section through a stoma.

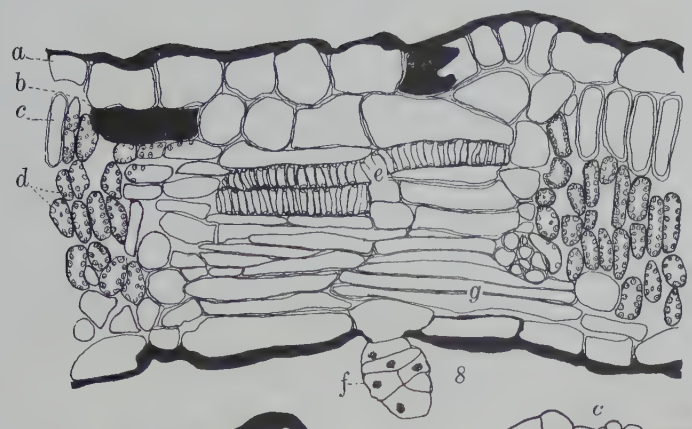
FIG. 11. Tangential section of leaf, × 275: *a*, vein; *b*, ending of vein; *c*, palisade cells.

FIG. 12. Tangential section through palisade cells, × 275.

FIG. 13. Tangential section showing epidermis, × 275: *a*, stoma; *b*, mucilagenous cell.

FIG. 14. Tangential section showing large border parenchyma cells beneath vein, × 275.

PLATE LV.



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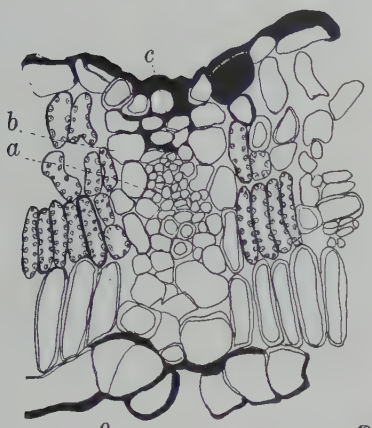

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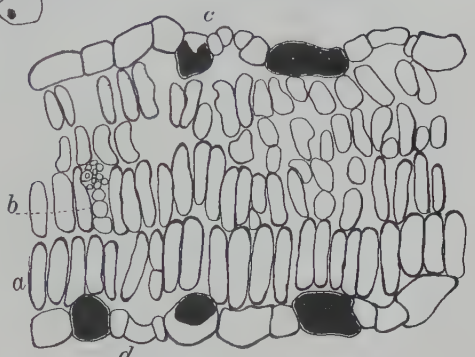

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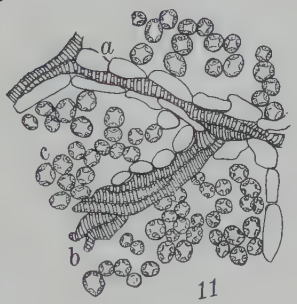

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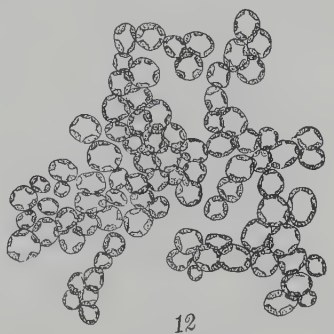
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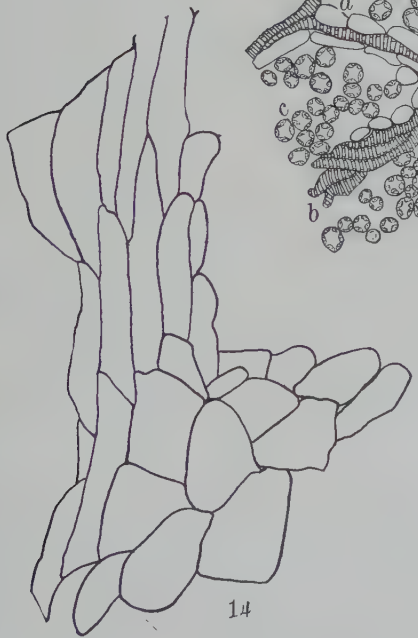
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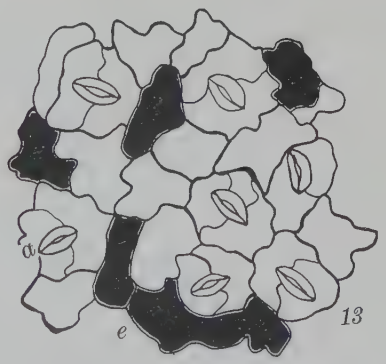


13

PLATE LVI.

FIG. 15. Cross section of stem showing distribution of mucilage, × 75: *m*, mucilage cells.

FIG. 16. Oblique section of stem showing distribution of mucilage, × 70: *e*, pocket where mucilage has dropped out; *d*, pocket containing mucilage.

FIG. 17. Cross section of stem showing distribution of crystals of calcium oxalate at *a*, × 20.

FIG. 18. Wood fiber, × 120.

FIG. 19. Crystals of calcium oxalate, × 375.

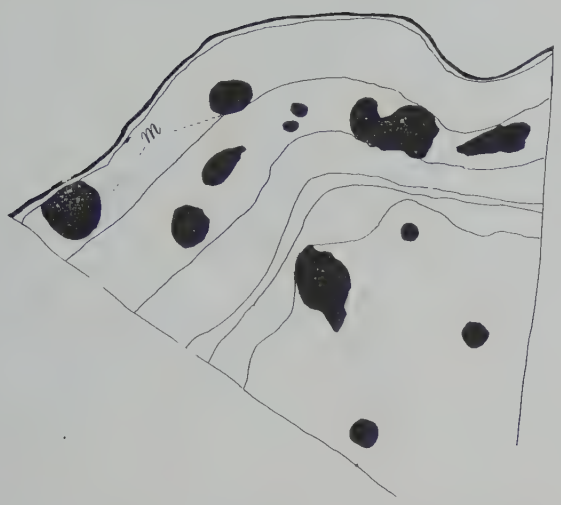
FIG. 20. Starch grains in stem, × 375.

FIG. 21. Starch grains in root, × 375.

FIG. 22. Cross section of petiole of leaf, × 70: *a*, vascular bundle; *b*, parenchyma of the cortex; *c*, collenchyma; *d*, glandular hair; *e*, epidermis.

FIG. 23. Vascular bundle of petiole, × 275: *a*, phloëm; *b*, tracheal tubes.

PLATE LVI.



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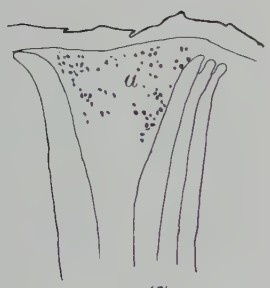

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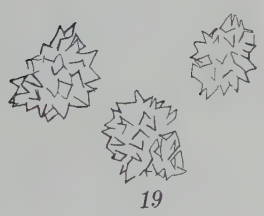

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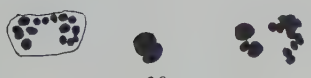

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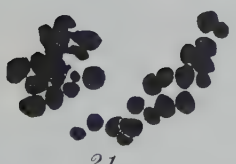

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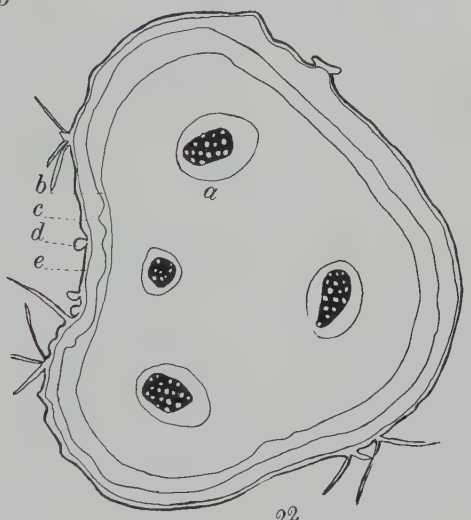

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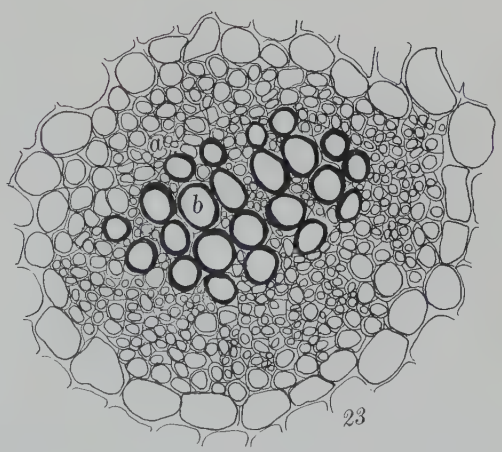

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PLATE LVII.

FIG. 24. Cross section of young stem, × 160: *a*, greatly swollen mucilage cavity; *b*, collenchyma; *c*, parenchyma of the cortex.

FIG. 25. Cross section of mid part of stem, × 160: *a*, mucilage cell.

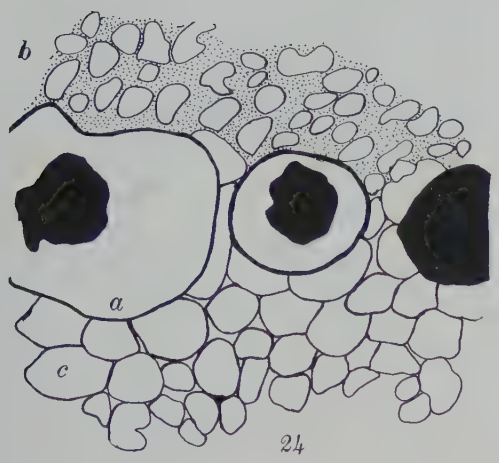
FIG. 26. Cross section of base of stem, × 160: *a*, mucilage cell.

FIG. 27. Cross section of old part of stem showing distribution of mucilage, × 25: *a*, collenchyma; *b*, parenchyma; *c*, bast fibers; *d*, phloëm; *e*, pith; *m*, mucilage.

FIG. 28. Cross section of young stem, × 25: *a*, collenchyma; *b*, parenchyma; *c*, bast fibers; *d*, phloëm; *e*, pith; *m*, mucilage.

FIG. 29. Cross section of a part of the root showing distribution of mucilage, × 25: *m*, mucilage.

PLATE LVII.



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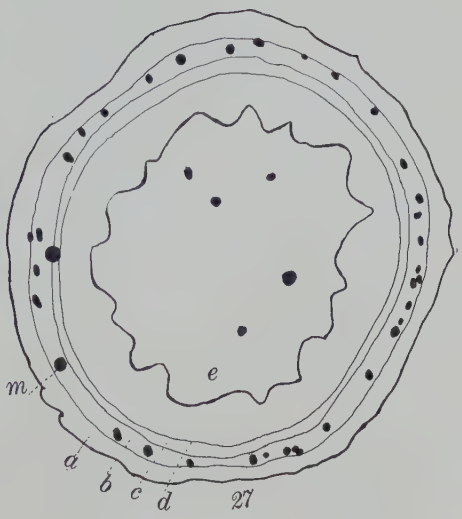

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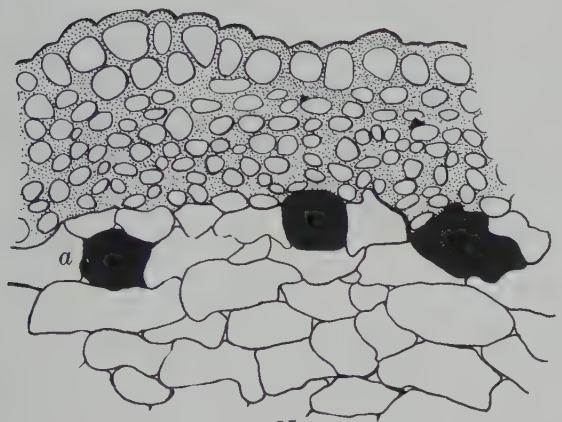

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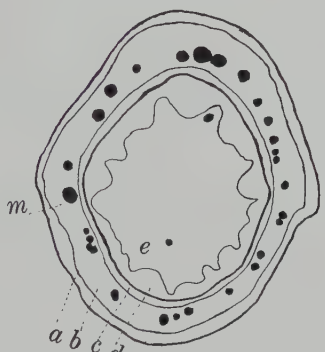

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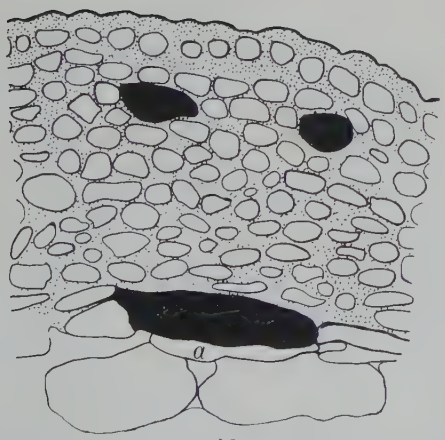

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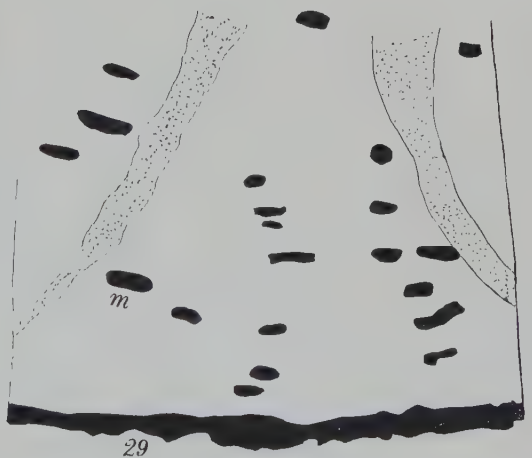


29

PLATE LVIII.

FIG. 30. Cross section of very young stem, × 25: *a*, multiple epidermis; *a'*, collenchyma; *b*, parenchyma; *c*, starch sheath; *d*, phloëm; *e*, xylem; *f*, pith.

FIG. 31. Cross section of a slightly older part of the same stem, × 25. Index same as for fig. 30.

FIG. 32. Section of same stem slightly older, × 25. Index same as for fig. 30, except *i*, bast fibers.

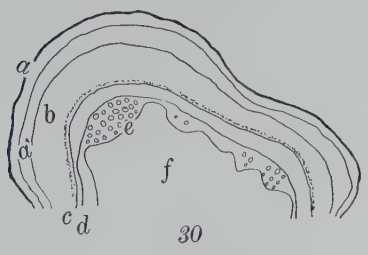
FIG. 33. Older section of the same stem, × 25. Index the same as for fig. 32.

FIG. 34. Older section of stem, × 25: *a*, cork tissue; *b*, starch sheath; *c*, original bast fiber bundle; *d*, bast produced by the cambium; *f*, water tubes; *g*, pith.

FIG. 35. Older part of stem, × 25. Index same as for fig. 34.

FIG. 36. Cross section of root, × 25: *a*, cork; *b*, parenchyma of the cortex; *c*, parenchyma of the pericycle and of the medullary rays, filled with starch; *d*, phloëm tissue; *f*, water-conducting tissue.

PLATE LVIII.



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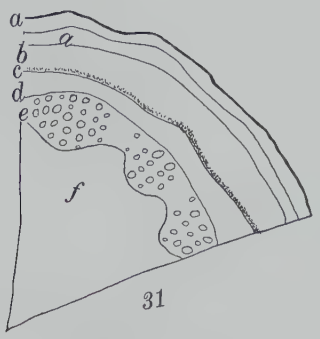

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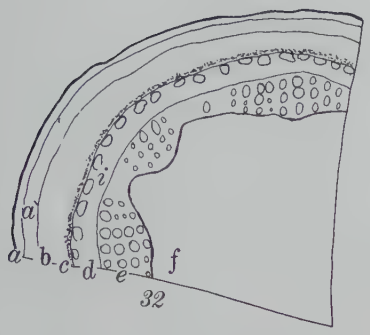

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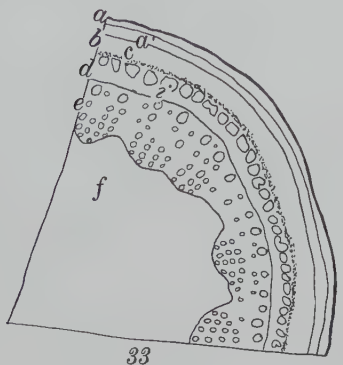

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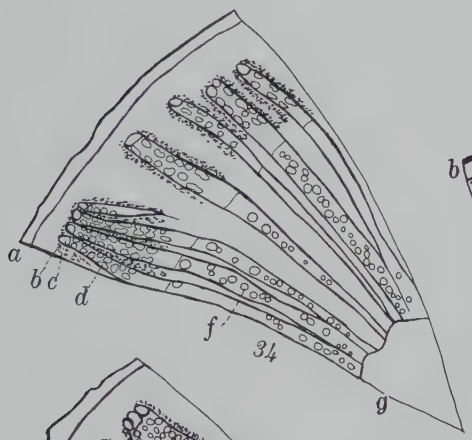

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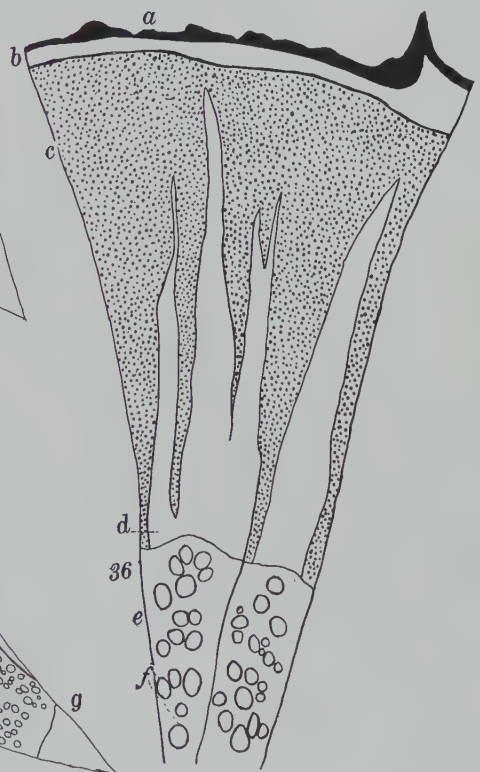

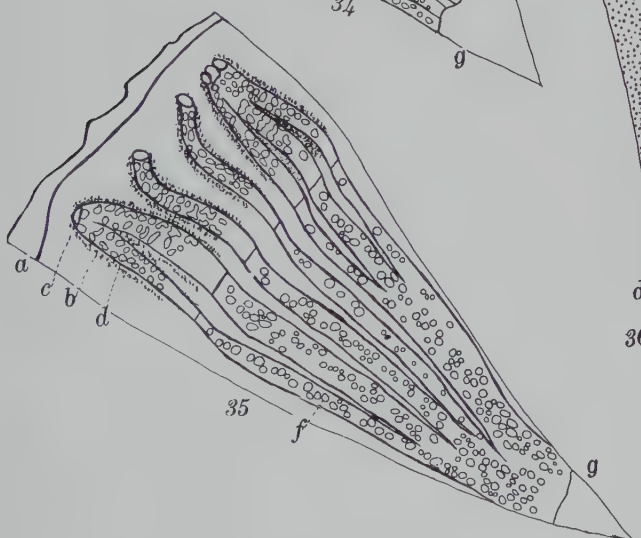

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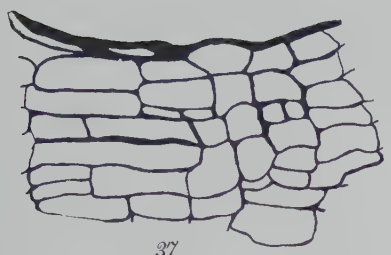
PLATE LIX.

FIG. 37. Cork tissue of the old stem, × 25.
FIG. 38. Original bast fiber bundle, × 25.
FIG. 39. Bast fiber bundle produced by cambium, × 25.
FIG. 40. Phloëm tissue, × 25.
FIG. 41. Water conducting tissue, × 25.
FIG. 42. Water tubes next to the pith, × 25.

PLATE LIX.



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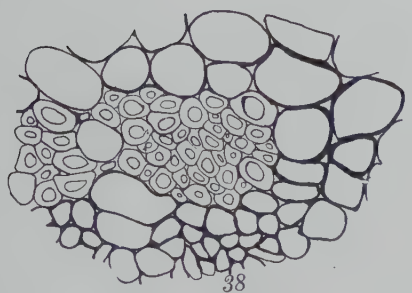

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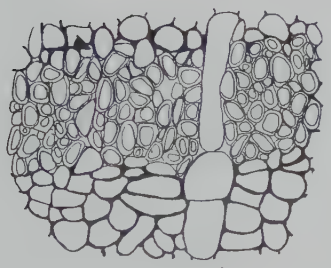

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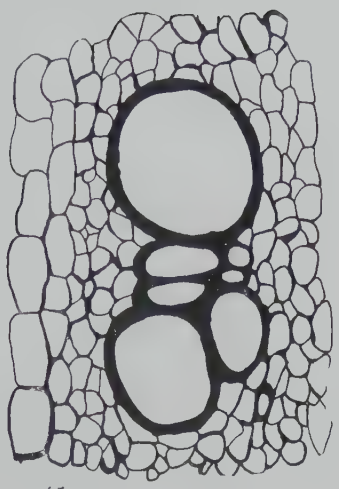

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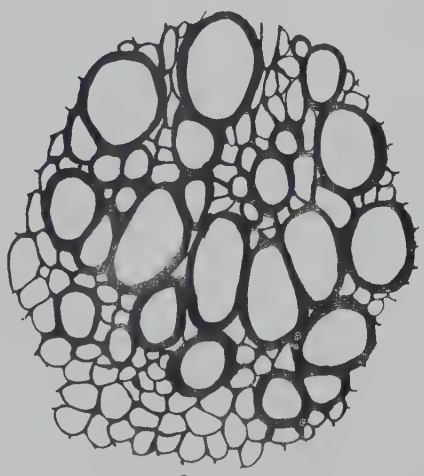

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PLATE LX.

FIG. 1. Typical leaf of *Q. rubra*, × ½.
FIG. 2. Typical leaf of *Q. schneckii*, × ½.
FIG. 3. Typical leaf of *Q. coccinea*, × ½.
FIG. 4. Typical leaf of *Q. macrocarpa*, × ½.
FIG. 5. Upper epidermis and palisade cells of *Q. rubra*, × 275.
FIG. 6. Upper epidermis and palisade cells of *Q. schneckii*, × 275.

PLATE LX.

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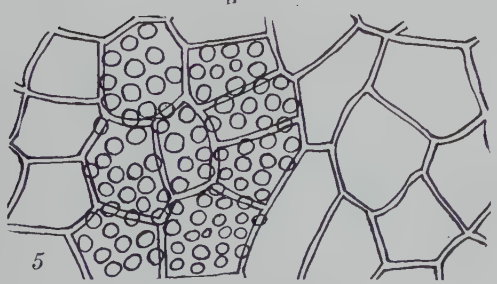
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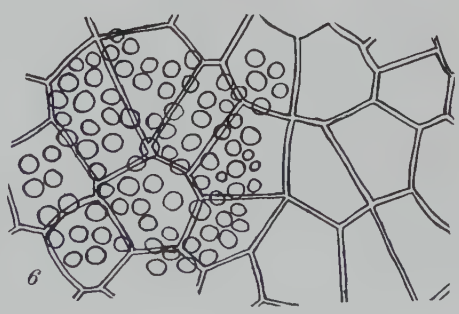
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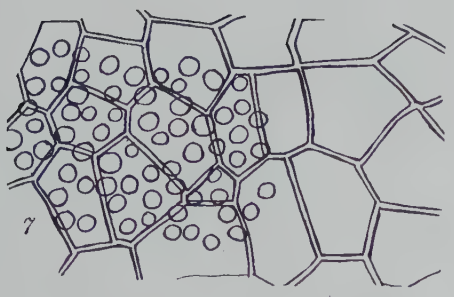
PLATE LXI.

FIG. 7. Upper epidermis and palisade cells of *Q. coccinea*, × 275.
FIG. 8. Upper epidermis and palisade cells of *Q. macrocarpa*, × 275.
FIG. 9. Lower epidermis of leaf of *Q. rubra*, × 275.
FIG. 10. Lower epidermis of leaf of *Q. schneckii*, × 275.
FIG. 11. Lower epidermis of leaf of *Q. coccinea*, × 275.
FIG. 12. Lower epidermis of leaf of *Q. macrocarpa*, × 275.
FIG. 13. Cross section of leaf of *Q. rubra*, × 235.
FIG. 14. Cross section of leaf of *Q. schneckii*, × 235.
FIG. 15. Cross section of leaf of *Q. coccinea*, × 235.
FIG. 16. Cross section of leaf of *Q. macrocarpa*, × 235.

PLATE LXI.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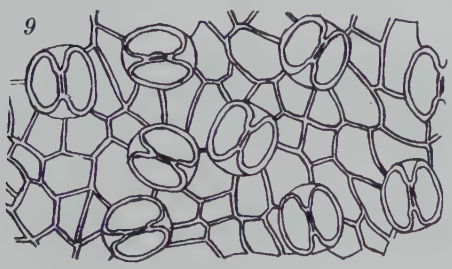
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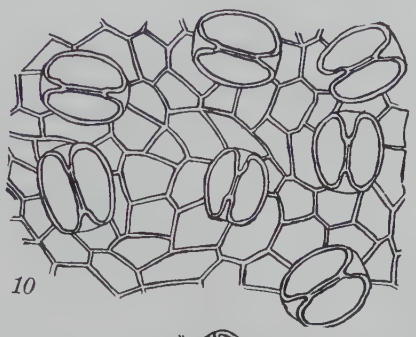
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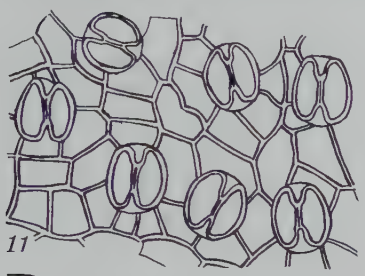
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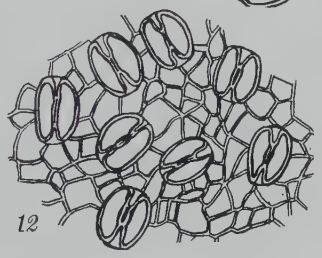
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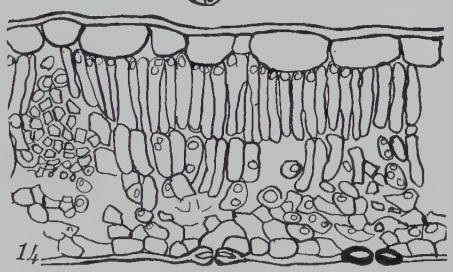
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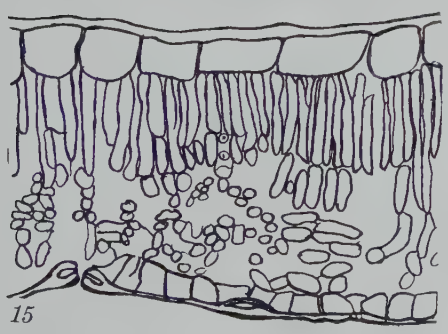
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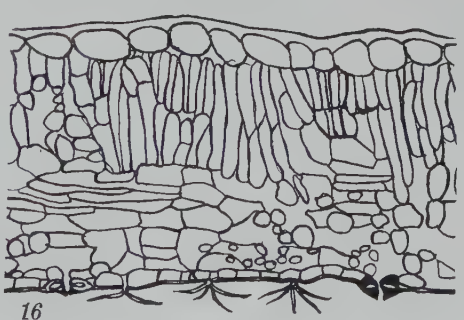
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PLATE LXII.

FIGS. 17, 18, and 19. Cross section of midrib of *Q. rubra*, showing manner of ending of middle vascular bundle. Phloëm stippled.

FIGS. 20, 21, and 22. Cross section of midrib of *Q. coccinea*, showing manner of ending of middle vascular bundle. Phloëm stippled.

FIGS. 23, 24, and 25. Cross section of midrib of *Q. schneckii*, showing manner of ending of middle vascular bundle. Phloëm stippled.

FIGS. 26, 27, 28, 29, and 30. Cross section of midrib of *Q. macrocarpa*, showing manner of ending of middle vascular bundle. Phloëm stippled.

FIG. 31. Cross section of stem of *Q. rubra*, current year: *w*, pith; *x*, xylem; *y*, phloëm; *z*, bast. × 12.

FIG. 32. Cross section of stem of *Q. schneckii*, current year: *w*, *x*, *y*, and *z* same as in fig. 31. × 12.

FIG. 33. Cross section of stem of *Q. coccinea*, current year: *w*, *x*, *y*, and *z* same as in fig. 31. × 12.

FIG. 34. Cross section of stem of *Q. macrocarpa*, current year: *w*, *x*, *y*, and *z* same as in fig. 31. × 12.

FIG. 35. Wood fiber of *Q. macrocarpa*. × 55.

FIG. 36. Bast fiber of *Q. macrocarpa*. × 55.

FIG. 37. Wood fiber of *Q. rubra*. × 55.

FIG. 38. Bast fiber of *Q. rubra*. × 55.

FIG. 39. Wood fiber of *Q. schneckii*. × 55.

FIG. 40. Bast fiber of *Q. schneckii*. × 55.

FIG. 41. Wood fiber of *Q. coccinea*. × 55.

FIG. 42. Bast fiber of *Q. coccinea*. × 55.

PLATE LXII.

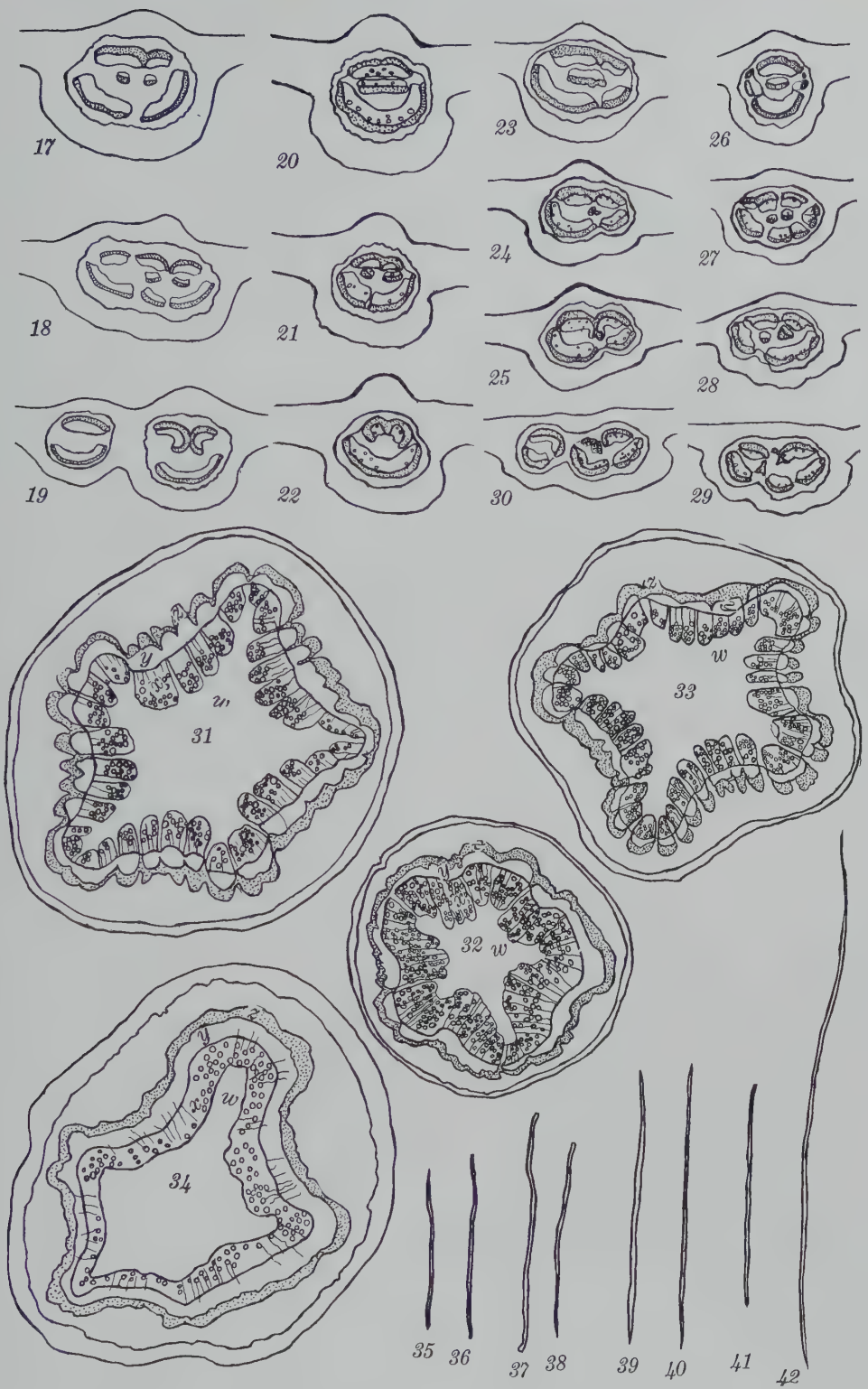
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PLATE LXIII.

FIG. 43. Cross section of stem of *Q. schneckii*, in the fourth year, showing tracheal tubes, medullary rays, and bark. Bast stippled. × 25.

FIG. 44. Cross section of stem of *Q. macrocarpa*, showing the same elements. × 25.

FIG. 45. Cross section of stem of *Q. coccinea*, showing the same elements. × 25.

FIG. 46. Cross section of stem of *Q. rubra*, showing the same elements. × 25.

PLATE LXIII.

PLATE LXIV.

FIG. 47. Tangential section of stem of *Q. rubra*, showing the number and size of medullary rays. × 52.

FIG. 48. Tangential section, showing same for *Q. schneckii*. × 52.

FIG. 49. Tangential section, showing same for *Q. coccinea*. × 52.

FIG. 50. Tangential section, showing same for *Q. macrocarpa*. × 52.

FIG. 51. Acorn of *Q. rubra*. × ½.

FIG. 52. Acorn of *Q. schneckii*. × ½.

FIG. 53. Acorn of *Q. coccinea*. × ½.

FIG. 54. Acorn of *Q. macrocarpa*. × ½.

FIG. 55. Cross section of shell of *Q. rubra*. × 23.

FIG. 56. Cross section of shell of *Q. schneckii*. × 23.

FIG. 57. Cross section of shell of *Q. macrocarpa*. × 23.

FIG. 58. Cross section of shell of *Q. coccinea*. × 23.

PLATE LXIV.

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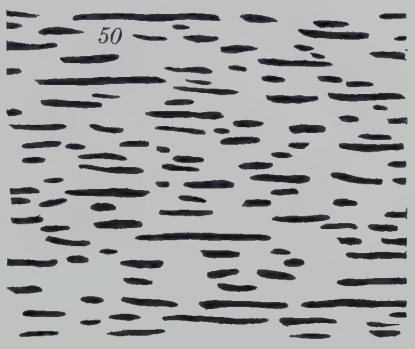
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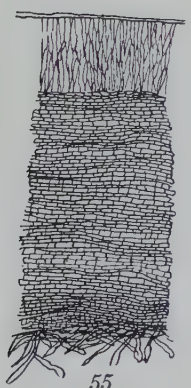
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PLATE LXV.

FIG. 1. Multicellular clothing hair of the epidermis of a very young leaf. × 110.

FIG. 2. Cross section of the midrib of a very young leaf: *m*, clothing hair; *a*, glandular hair; *y*, epidermis; *n*, parenchyma; *r*, cells which will develop into bast fibers; *o*, phloëm; *x*, tracheal tubes. × 110.

FIG. 3. Cross section of the midrib of a somewhat older leaf: *y*, epidermis; *n*, parenchyma; *r*, cells which will develop into bast fibers; *o*, phloëm; *x*, xylem. × 110.

FIG. 4. Cross section of the midrib of a mature leaf: *y*, epidermis; *n*, parenchyma; *r*, bast fibers; *o*, phloëm; *x*, xylem. × 110.

PLATE LXV.

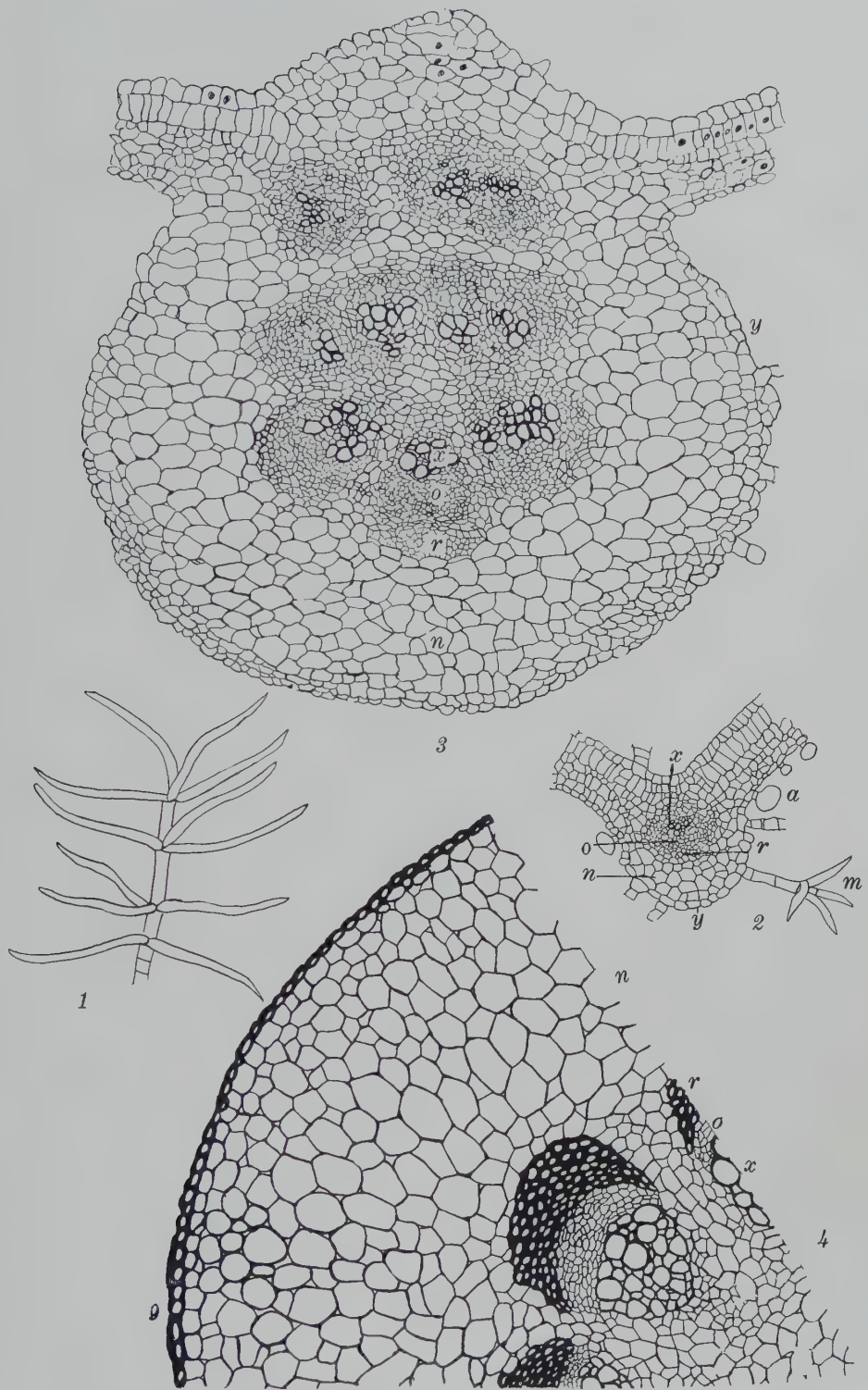


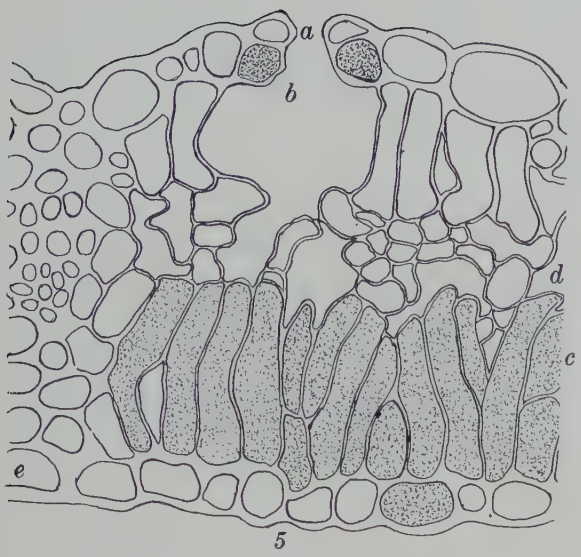
PLATE LXVI.

FIG. 5. Cross section of a leaf stained with methylene blue. Stippling indicates cells whose contents stained a deep blue: *a*, guard cells; *b*, epidermal cell beneath guard cell; *d*, spongy parenchyma; *c*, palisade cells; *e*, upper epidermis. × 400.

FIG. 6. Lower epidermis of leaf: *a*, guard cell; *b*, epidermal cell beneath guard cell whose contents took a deep stain with methylene blue. × 400.

FIG. 7. Surface view of a bleached leaf embracing the epidermal, the palisade, and the vascular bundle systems. × 183.

PLATE LXVI.



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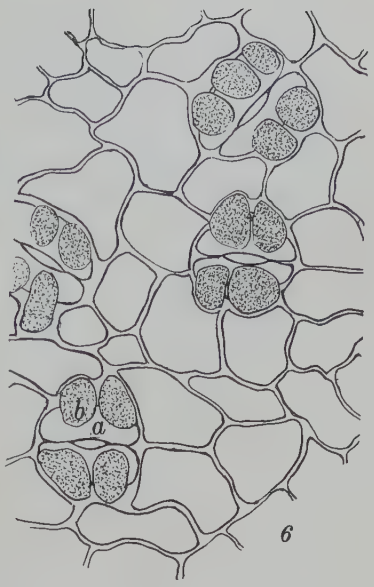

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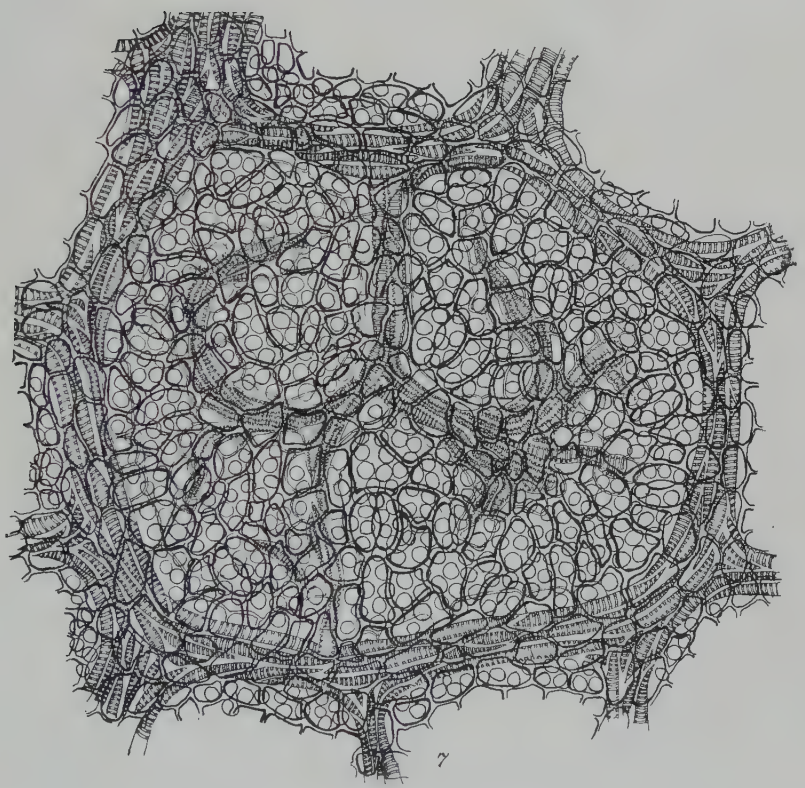

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PLATE LXVII.

FIG. 8. An oblique section of a leaf nearly parallel to the surface and embracing zones from surface to surface. Stained with methylene blue. Stippling indicates cells whose contents were deeply stained: *g*, upper epidermis; *h*, palisade cells; *k*, border parenchyma; *t*, tracheid with annular thickenings; *j*, lower epidermis; *r*, stoma. × 187.

PLATE LXVII.

PLATE LXVIII.

FIGS. 9 to 19, inclusive, are cross sections of the midrib of a leaf, the sections being cut at intervals from the tip to the base of the leaf blade. The xylem and bast fibers are colered black in figures 9 to 29, inclusive. × 20.

FIG. 19, *b*, bast fibers; *x*, xylem.

FIG. 20. Cross section of the petiole of a leaf just below the base of the leaf blade, showing two rings of vascular bundles. × 20.

FIG. 21. Cross section of petiole. This diagram represents the typical arrangement of the vascular bundles in the petiole. × 20.

FIG. 22. Cross section of petiole a short distance above the base. × 40.

FIG. 23. Cross section of petiole just above the hollow in which the axillary bud lies. × 20.

FIG. 24. Cross section of petiole, showing the hollow, *h*, in which the axillary bud lies. × 20.

PLATE LXVIII.

PLATE LXIX.

FIGS. 25 to 29. A series of cross sections of the stem proceeding downward. Stippled region, *w*, indicates stone cells.

FIG. 25. Section just below terminal bud showing strands of leaf trace, *t*, *u*, *v*, *w*, *x*, *y*, and *z*, just before they enter the vascular ring of the stem. × 8.5.

FIG. 26. *t* and *z* are taking their places in the vascular rings of the stem; *w* is about to enter. × 8.5.

FIG. 27. *t*, *z*, and *w* are in the vascular ring of the stem. The other strands are approaching the ring. × 8.5.

FIG. 28. *t*, *v*, *w*, *x*, and *z* have now entered the vascular ring of the stem. Strands *u* and *y* are almost within the leaf trace gaps. × 8.5.

FIG. 29. All the leaf trace strands have occupied the leaf trace gaps. × 8.5.

FIG. 30. Twig showing terminal bud and lateral bud. × 1.25.

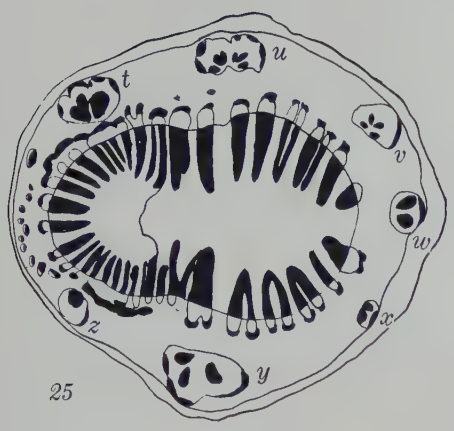
FIG. 31. Longitudinal section of terminal bud: *s*, outer scale; *t*, second bud scale covered with hairs and resin; *u*, third bud scale, and *v*, hairs growing from this scale; *w*, inflorescence; *x*, section through leaf. × 3.5.

FIG. 32. Cross section of bud through inflorescence. Lettering same as in fig. 31. × 3.5.

FIG. 33. Cross section of bud below inflorescence; *z*, peduncle. The other letters as in figs. 31 and 32. × 3.5.

FIG. 34. Dissection of bud: *a*, outer bud scale; *b*, second bud scale; *c*, bud after the two outer bud scales have been removed showing leaf, *s*, outside the third bud scale; *d*, leaf outside the third bud scale; *f*, *g*, *h*, and *i*, leaves in order from the outside in; *j*, inflorescence. × 3.5.

PLATE LXIX.



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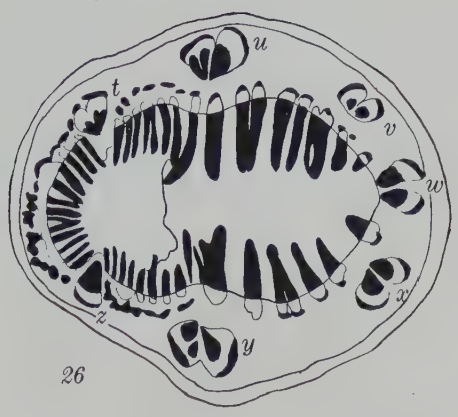

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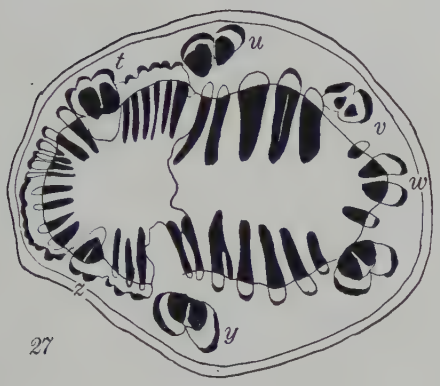

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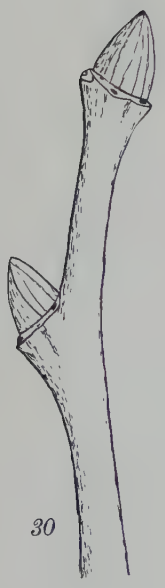

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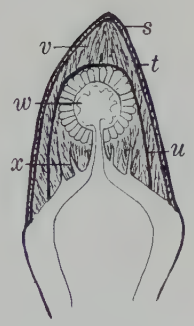

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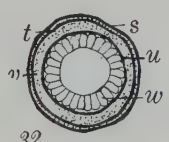

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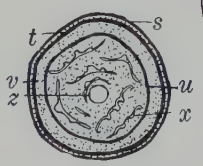

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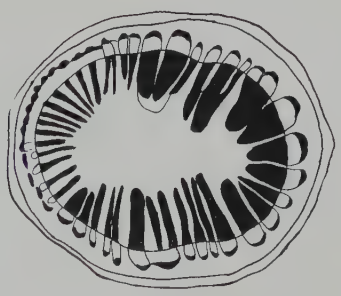

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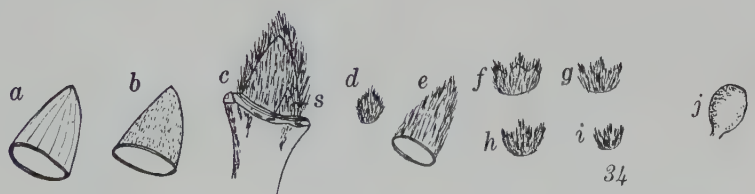

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PLATE LXX.

FIG. 35. Cross-section of the peduncle: *g*, bast fibers; *f*, phloëm; *e*, xylem; *r*, medullary ray. × 47.

FIG. 36. Cross-section of peduncle: *d*, pith; *e*, phloëm; *f*, xylem; *h*, pith with thickened walls; *i*, xylem; *j*, phloëm; *k*, bast fibers; *l*, parenchyma; *m*, epidermis. × 158.5.

PLATE LXX.

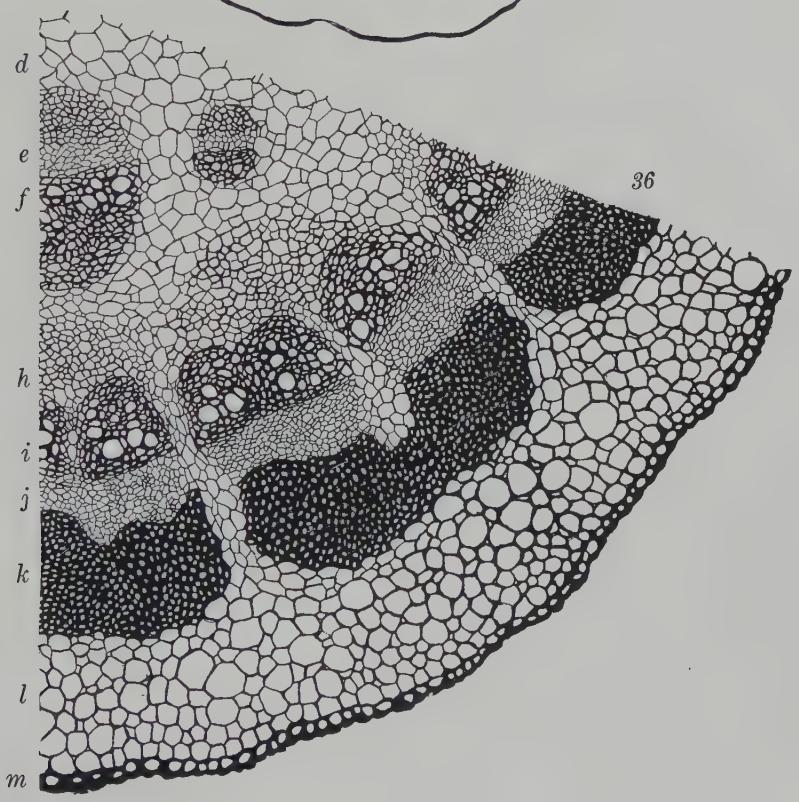


PLATE LXXI.

FIGS. 37 to 42, inclusive. A series of cross sections of the stem starting just above the base of the terminal bud and proceeding downward, showing how the rings of vascular bundles of three separate buds merge into the one ring of the stem which bears them. The xylem and bast fibers are colored black. × 13.5.

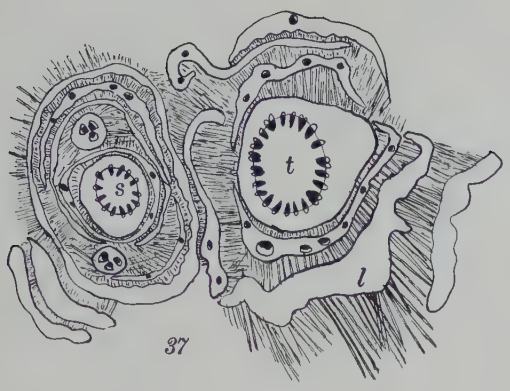
FIG. 37. Cross section showing the vascular bundles of two buds, *s* and *t*. The outer bud scales have been removed: *l*, leaf. × 13.5.

FIG. 38. *s* and *t* are closer together. There is stem tissue instead of leaves between them. × 13.5.

FIG. 39. *s* and *n* are approaching *t*. × 13.5.

FIG. 40. The ring, *t*, is opening to receive *s* and *n*. × 13.5.

PLATE LXXI.



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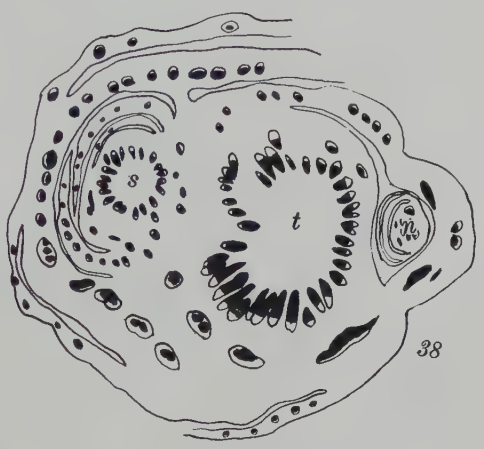

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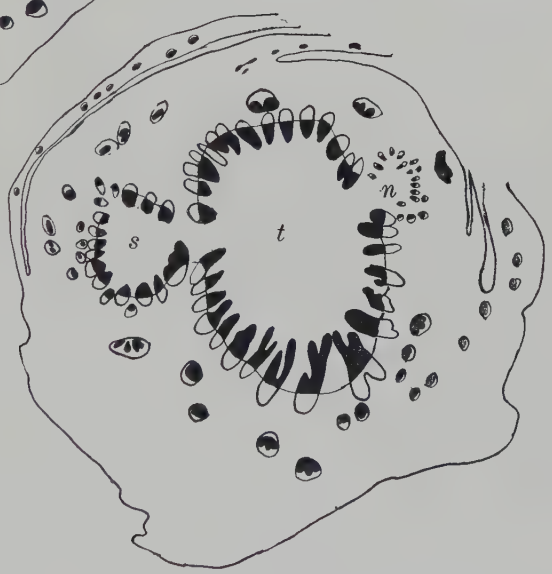

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PLATE LXXII.

FIG. 41. *s*, *t*, and *n* are forming one ring. × 13.5.
FIG. 42. *s*, *t*, and *n* have merged into one ring. × 13.5.

PLATE LXXII.

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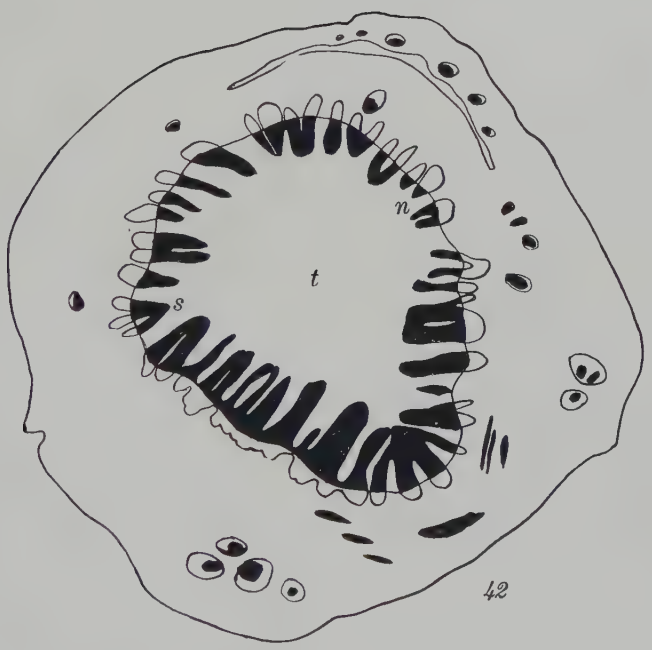

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PLATE LXXIII.

FIG. 43. Cross section of the bark of a stem five years old: *c*, cork; *b*, bast fibers; *l*, lignified tissue with the exception of the bast fibers; *u*, unlignified tissue. × 41.5.

FIG. 44. Cross section of bark: *c*, cork; *j*, parenchyma; *b*, bast fibers; *p*, phloëm; *m*, medullary ray. × 100.

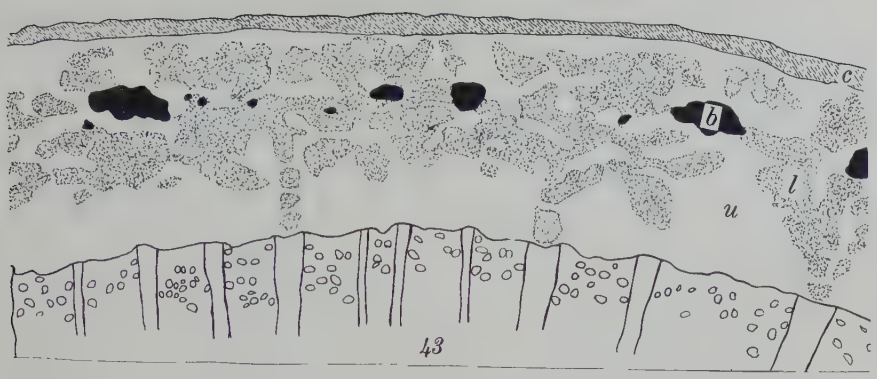
FIG. 45. Longitudinal section of the bark: *c*, cork; *j*, parenchyma; *b*, bast fibers; *m*, medullary rays; *p*, phloëm. × 100.

FIG. 46. Cross section of bark: *b*, bast fibers; *j*, parenchyma; *s*, stone cells; *p*, phloëm; *i*, sieve plate. Stippling indicates lignified tissue. × 277.5.

FIG. 47. Longitudinal section of the bark. Lettering same as in fig. 46. × 555.

FIG. 48. Bast fiber of medium length from the bark. × 277.5.

PLATE LXXIII.



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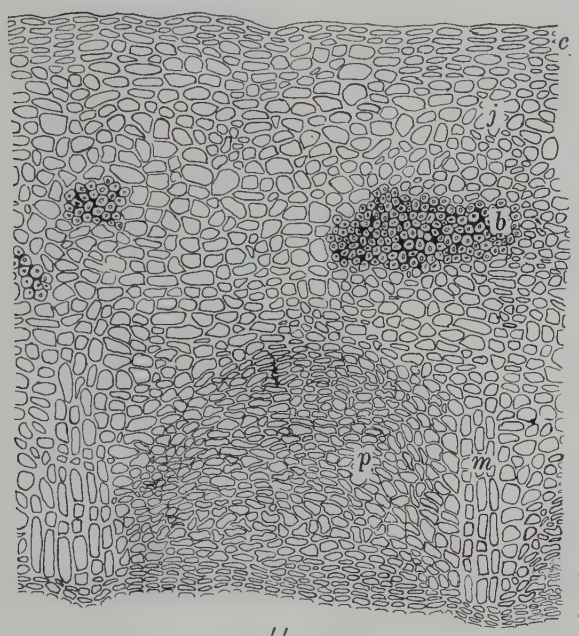

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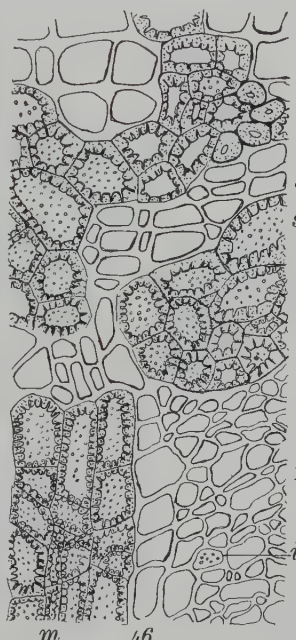

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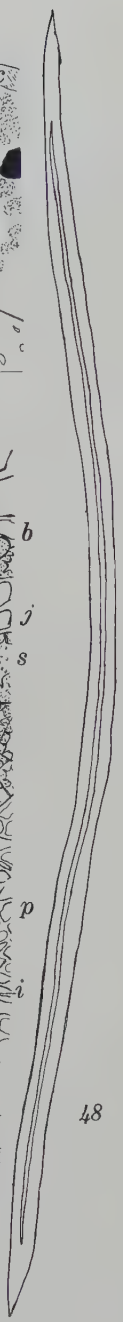

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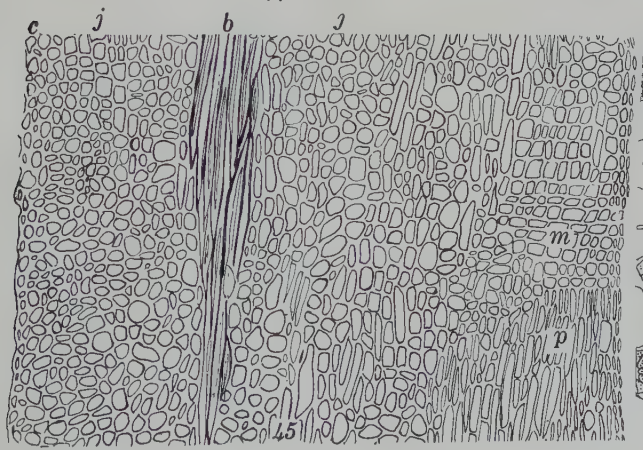

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PLATE LXXIV.

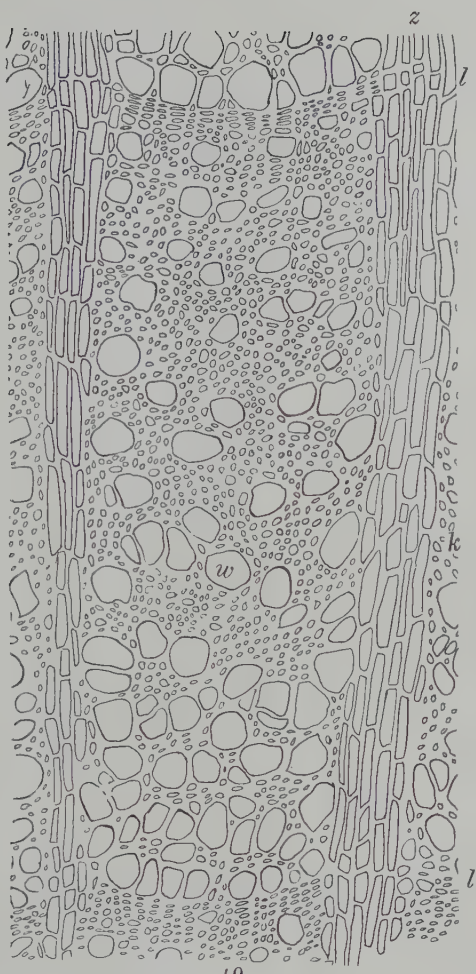
FIG. 49. Cross section of wood: *l, l,* limits of a year's growth; *z,* medullary ray; *w,* tracheal tube; *k,* fiber tracheids. × 85.

FIG. 50. Longitudinal section of wood: *z,* medullary rays; *w,* fiber tracheids. × 85.

FIG. 51. Cross section of wood: *z,* medullary rays; *w,* tracheal tube; *k,* fiber tracheids; *v,* wood parenchyma. × 155.

FIG. 52. Longitudinal section of wood. Lettering same as in fig. 51. × 155.

PLATE LXXIV.



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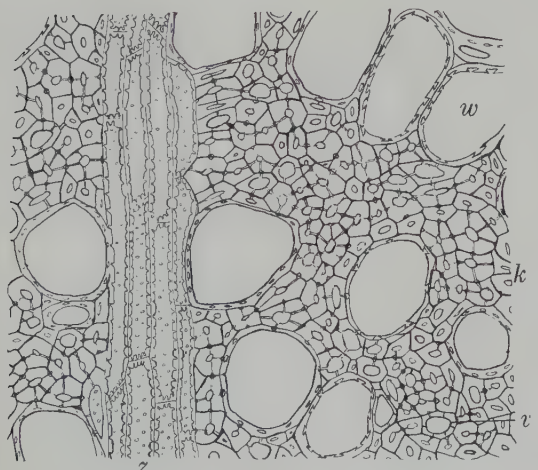

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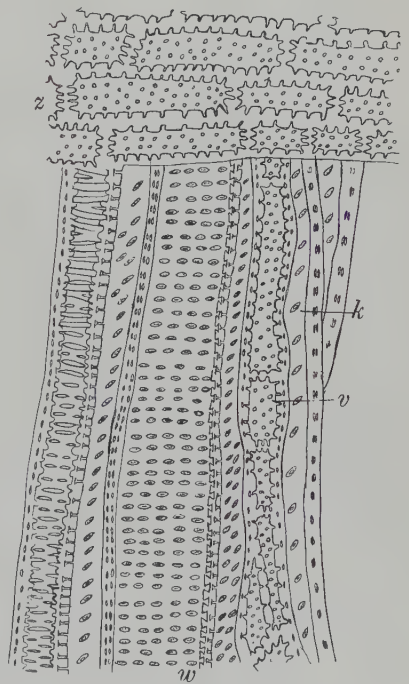

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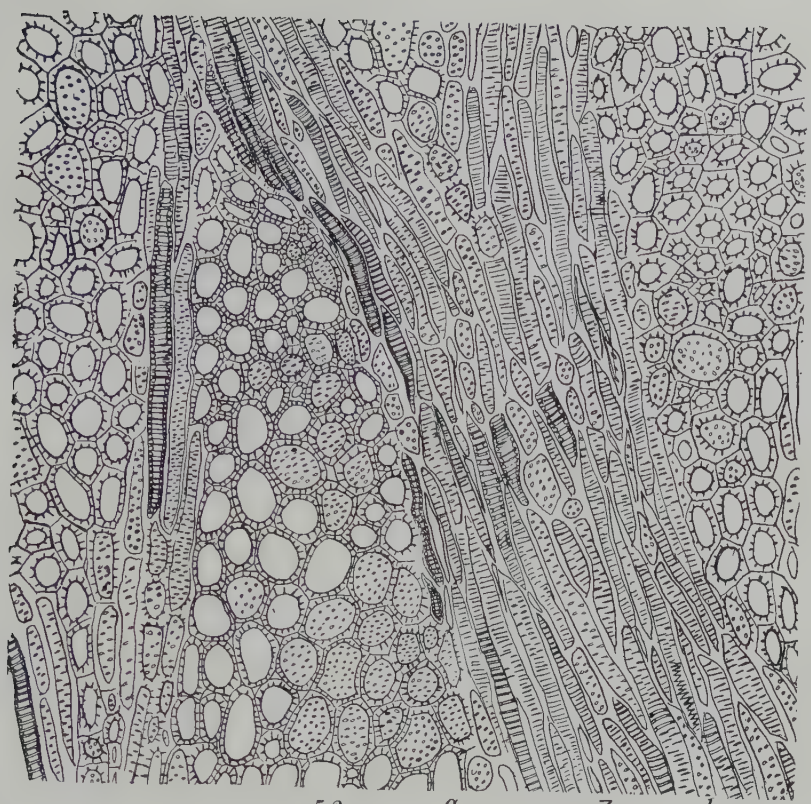
PLATE LXXV.

FIG. 53. Longitudinal section of the wood under the terminal bud: *q*, stone cells; *z*, tracheids; *l*, wood parenchyma. × 260.

FIG. 54. Tangential section of the wood showing end view of medullary rays and their frequency per square millimeter. The square represents a square millimeter: *m*, medullary ray. × 21.

FIG. 55. A bast fiber from the wood. × 137.5.

PLATE LXXV.



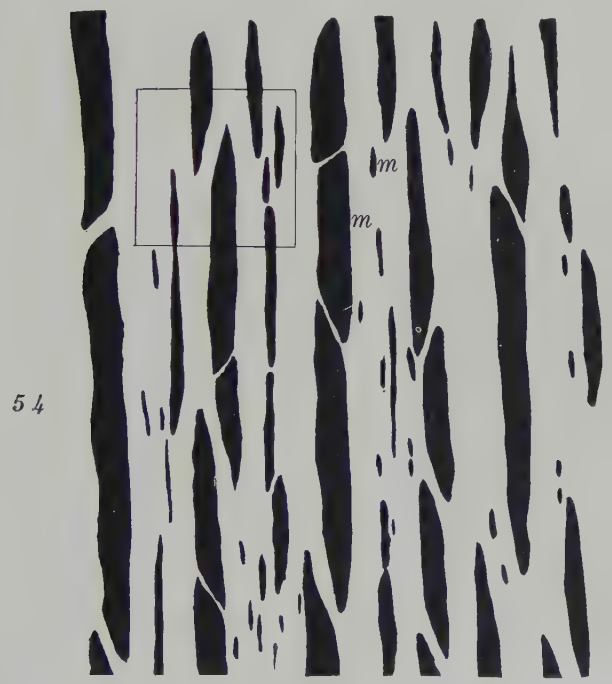


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PLATE LXXVI.

FIG. 56. Cross section of stem below terminal bud: *q*, wedges of xylem of the vascular bundle system; *r*, leaf trace; *h*, bundles of bast fibers; *l*, medullary rays. × 18.

FIG. 57. Longitudinal section of the stem below the terminal bud, showing the anastomosing of the vascular bundles: *l*, medullary ray; *q*, vascular bundle; *h*, bundle of bast fibers. × 18.

FIG. 58. Longitudinal section through old and new growth of stem: *j*, xylem of new growth; *l*, xylem of the last year's growth; *h*, bundle of bast. × 18.

FIG. 59. Longitudinal section of pith: *d*, pith of the last year's growth; *c*, pith of current year. Stippling indicates cell contents. × 173.

PLATE LXXVI.

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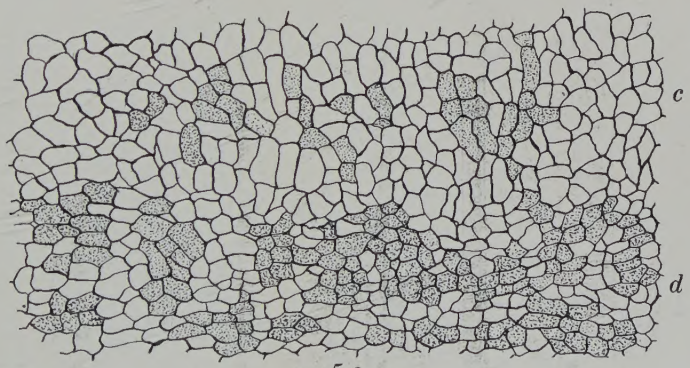
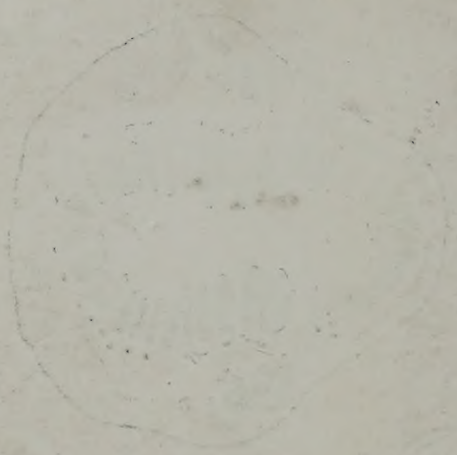
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